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Molluscan Paleontology, Paleoecology, and North Pacific Correlations of the Miocene Tachilni Formation, Alaska Peninsula, Alaska

by
Louie Marincovich, Jr.

Paleontological Research Institution
1259 Trumansburg Road
Ithaca, New York, 14850 U.S.A.

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MOLLUSCAN PALEONTOLOGY, PALEOECOLOGY, AND NORTH PACIFIC CORRELATIONS OF THE MIOCENE TACHILNI FORMATION, ALASKA PENINSULA, ALASKA

By

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ABSTRACT

The Tachilni Formation, composed mainly of fine- to medium-grained sandstone, crops out near the western end of the Alaska Peninsula, southwestern Alaska, and contains 53 molluscan taxa, including 36 bivalves and 17 gastropods. The high percentage of articulated, closed bivalve shells, including some found in life positions, suggests that Tachilni deposits were largely unaffected by post-mortem transport. The mollusks are inferred to have lived in a cool-temperate, inner shelf habitat.

Many of the mollusks are known in Miocene faunas of Asia (Hokkaido, Sakhalin, Kamchatka) as well as western North America (California, Oregon, Washington). Several of the North American taxa suggest an age of early late Miocene (Wishkahan Stage) for the Tachilni fauna. Reliable correlations may be made with the Etolon Formation of western Kamchatka, the middle part of the Bear Lake Formation of the Alaska Peninsula, the lower to middle part of the Yakataga Formation of the eastern Gulf of Alaska, and the lower part of the Montesano Formation (type section of the Wishkahan Molluscan Stage) of southwestern Washington. Other possible correlatives of the Tachilni Formation are the Okkopezawa and Togeshita Formations of Hokkaido and the Nutovo Formation of Sakhalin.

Newly described species are *Cyclocardia sakamotoi* and *Lyonsia mooreae*.

要　　旨

Tachilni層は主に細粒ないし中粒砂岩からなり，アラスカ半島西端部近くに分布し，36種の二枚貝と17種の巻貝を含む53種の貝化石を産する。若干の生時の状態で産出するものを含め両殻合弁で産出する二枚貝の比率は大きく，Tachilniの堆積は死後運搬された種の影響をあまり受けていない。これらの貝類は冷一温暖な上部陸棚上に生息していたと推定される。

これらの貝類の多くは北米西部（カリフォルニア，オレゴン，ワシントン）と同様にアジア（北海道，樺太，カムチャツカ）の中新世貝類動物群にも知られている。いくつかの北米種はTachilni貝類動物群が後期中新世初期（Wishkahan階）を示している。また，Tachilni層は西カムチャツカのEtolon層，アラスカ半島のBear Lake層中部，アラスカ湾東部のYakataga層中・下部及びワシントン南西部のMontesano層（貝類によるWishkahan階の模式）にほぼ確実に対比される。Tachilni層は北海道のオコッペザワ層と峠下層，および樺太のNutovo層とも対比が可能である。この論文で*Cyclocardia sakamotoi*と*Lyonsia mooreae*が新種として記載されている。

АВТОРЕФЕРАТ

Тачильная свита, состоящая главным образом из мелкозернистых и среднезернистых песчаников, выходит на поверхность около западного конца п-ова Аляска (юго-западная Аляска) и содержит 53 моллюсковых таксонов: 36 двустворчатых и 17 брюхоногих. Большое количество сочлененных замкнутых двустворчатых раковин (некоторые из которых даже находились в естественных прижизненных положениях) предлагает,что на Тачильные отложения в значительной степени не влияло перемещение раковин после смерти. Предполагается, что эти моллюски обитали в прохладно-умеренной среде прибрежной части материкового шельфа (до 100 м глубиной).

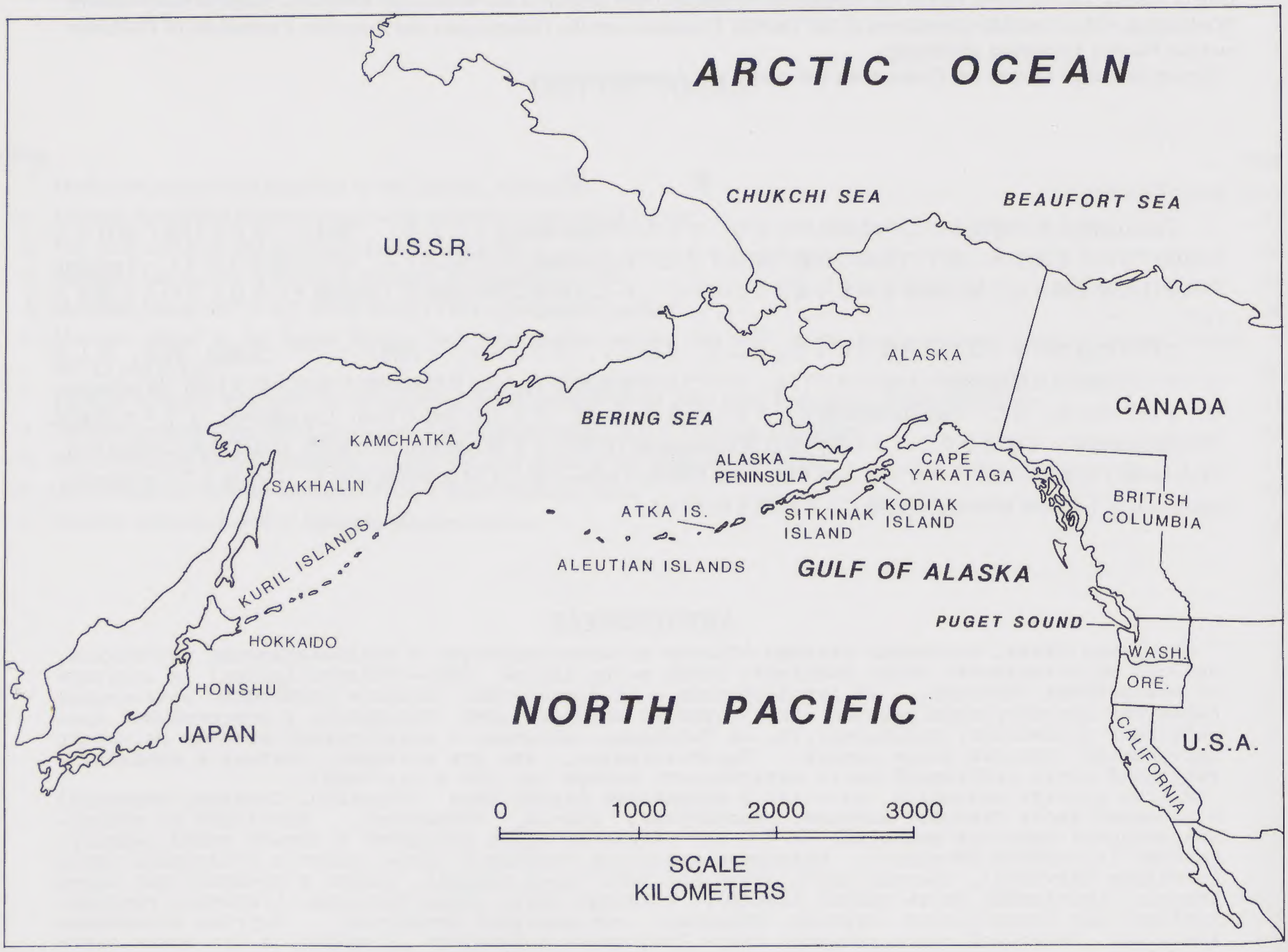
Многие из этих моллюсков известны в миоценовых фаунах Азии (Хоккайдо, Сахалин, Камчатка) и западной части Северной Америки (Калифорния, Орегон, Вашингтон). Некоторые из северо-американских таксонов указывают на то, что Тачильная фауна находится в нижней части верхнего миоцена (в периоде Уйшкахан). Надежными аналогами Тачильной свиты являются Этолонская свита (западная Камчатка), средняя часть свиты Бэр Лэйк (по-в Аляска), нижние и средние слои свиты Якатага (восточная часть залива Аляска), и нижняя часть свиты Монтесано (типичное местонахождение для моллюскового периода Уйшкахан; юго-западный Вашингтон). Другими возможными аналогами Тачильной свиты являются свиты Оккопезава и Тогешита (Хоккайдо) и Нутовская свита (Сахалин).

Новые описанные в этом труде виды являются: *Cyclocardia sakamotoi, Lyonsia mooreae.*

INTRODUCTION

The Tachilni Formation is a marine sandstone unit that crops out at the western end of the Alaska Peninsula in southwestern Alaska (Text-figs. 1, 2). The first published mention of fossils from beds now assigned to the Tachilni Formation was by Grewingk (1850), who reported fossil mollusks from Morzhovoi Bay, immediately west of Cape Tachilni (Text-figs. 2, 3) and discussed and illustrated numerous Mesozoic and Cenozoic mollusks from the Alaska Peninsula and adjacent islands. Unfortunately, none of the Morzhovoi Bay fossils was illustrated. Girard (1843) had previously described two Tertiary bivalves from Atka Island, Aleutian Islands, about 800 km (480 mi) southwest of Cape Tachilni, as well as other new mollusks from Kamchatka, U.S.S.R., but none from the Alaska Peninsula. Eichwald (1871) mistakenly assigned to the Cretaceous Girard's (1843) and Grewingk's (1850) Tertiary mollusks from Atka, Unga, and Kodiak Islands (Text-figs. 1, 2), but noted no additional species from the Alaskan mainland.

A summary of southern Alaskan Tertiary marine mollusks was presented by Dall and Harris (1892) and Dall (1896), who listed 46 molluscan taxa from the entire Gulf of Alaska region, including 24 taxa from the Alaska Peninsula, some from Unga and Kodiak Islands (Text-fig. 2). The authors in both works assigned all mollusks to the "Astoria group" and correlated them with Miocene strata at Astoria, Oregon. Most of the "Astoria group" mollusks listed from the Alaska Peninsula in Dall and Harris (1892) and Dall (1896) were collected by Dall and his associates during many summer field seasons. Collections made at Morzhovoi Bay came from the Tachilni Formation, and those made elsewhere on the Alaska Peninsula probably came from the Bear Lake Formation. These early collections more than tripled the number of Alaska Peninsula Tertiary mollusks reported by Grewingk (1850) and allowed Dall to speculate on correlations with Tertiary faunas elsewhere in southern Alaska as well as in California, Oregon and British Columbia, Canada. Brief mention of Tertiary mollusks from the

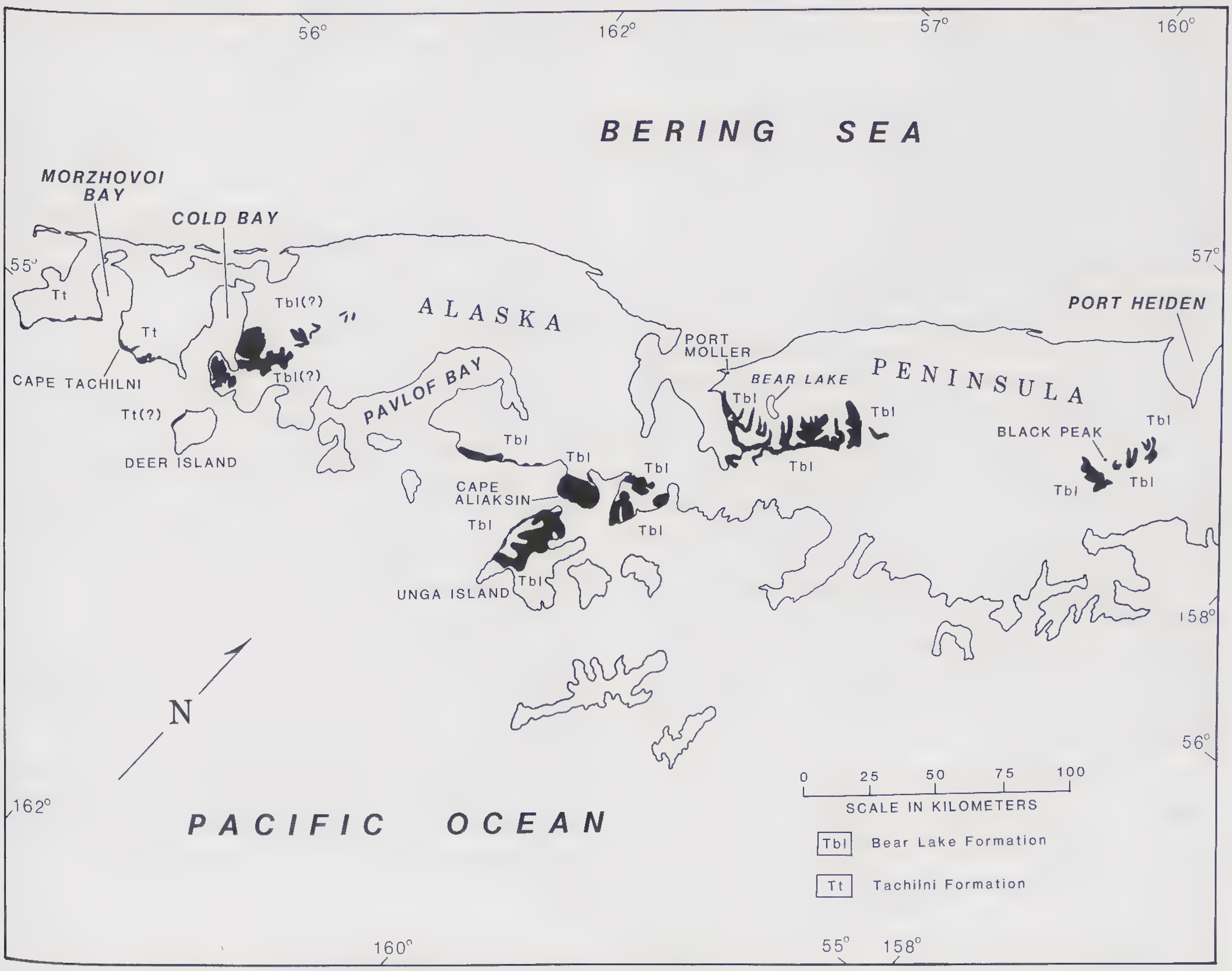


Text-figure 1.—Map of the North Pacific region, showing places mentioned in text.

western Alaska Peninsula was made by Dall (1904, 1908), though he did not cite species from the Cape Tachilni area.

Very few geologic investigations were made on the Alaska Peninsula, especially at its remote western end, for more than half a century after Dall's work (Waldron, 1961). The extraordinarily stormy climate, mountainous terrain with rockbound coasts, and difficulties of travel and logistics discouraged work in the area. Modern geologic reconnaissance studies of the western Alaska Peninsula began with Kennedy and Waldron (1955). Waldron (1961) named the Tachilni Formation and designated its type locality at Cape Tachilni (Text-fig. 3). Waldron's field party collected fossil marine mollusks and echinoids at Cape Tachilni, but these were later "lost in transit," and the Tachilni Formation was tentatively thought to be of "late Tertiary" age in lieu of fossil evidence (Waldron, 1961, p. 687). MacNeil *et al.* (1961, p. 1802, 1804) considered the Tachilni Formation, which they referred to as "Beds west of Cold Bay (marine)," to be of early Pliocene age, "based on collections by H. H. Waldron (unpublished)."

In subsequent years fossils were collected from the Tachilni Formation at infrequent intervals, mostly by U.S. Geological Survey and petroleum company field parties. Tachilni strata unfortunately were not examined by Burk (1965) during his monumental reconnaissance geologic study of the Alaska Peninsula. The first fossils named and illustrated from the type locality of the Tachilni Formation were two new mollusks described by MacNeil (1970). The use of helicopters in recent years has allowed extensive collecting of the Tachilni fauna, though no additional Tachilni mollusks have since been illustrated. The sand dollar echinoids from Cape Tachilni, including three new species, were



Text-figure 2.—Map showing outcrop extent of Tachilni and Bear Lake Formations on the Alaska Peninsula.

described and illustrated by Wagner (1974). Allison (1978) recognized 19 mollusk taxa in the Tachilni strata, and Marincovich (*in* McLean, Englehardt, and Howell, 1978) reported 31 mollusk taxa from the type-section and adjacent outcrops of the formation. Marincovich (1981b) later increased the recognized molluscan fauna to 53 species. The present study is an expanded treatment of the fauna that I noted in my 1981b report.

ACKNOWLEDGMENTS

This study would not have been possible without the invaluable helicopter support provided to me in June 1977 by my colleague at the U.S. Geological Survey in Menlo Park, CA, Hugh McLean. Most of the fossils reported on here were collected at that time. Some of McLean's unpublished information on the physical stratigraphy of the Tachilni Formation, especially regarding measured sections, is incorporated into this study. I would also like to thank Richard C. Allison, University of Alaska, College, AK, for the loan of fossils and discussions of taxonomic assignments during the early phase of this study. Barry Roth, California Academy of Sciences, San Francisco, CA, also provided thoughtful insight into the nomenclature of some taxa. Thanks are also due to Peter U. Rodda, California Academy of Sciences, for the loan of specimens, and to Kenji Sakamoto, U.S. Geological Survey, Menlo Park, CA, for his fine photographic work that illustrates the Tachilni fauna. The following individuals helpfully provided unpublished data and comments, which I have cited as oral or written communications in the text: John Barron, Kristin McDougall, and Hugh McLean, U.S. Geological Survey, Menlo Park, CA; Saburo Kanno, Joetsu University of Education, Niigata, Japan; Koichiro Masuda, Miyagi University of Education, Sendai, Japan; Hiroshi Noda, The University of Tsukuba, Ibaraki, Japan; Kenshiro Ogasawara, Tohoku University, Sendai, Japan, and, Judith Smith, Stanford University, Stanford, CA. I am also grateful for the perceptive reviews of this study by Barry Roth and by George L. Kennedy, U.S. Geological Survey, Menlo Park, CA. Special thanks are due to Hiroshi Noda for translating my abstract into Japanese, and to Scott Samuel, Los Altos, CA, for translating it into Russian.

PHYSICAL STRATIGRAPHY

The Tachilni Formation crops out along the rugged southern coastline at the western end of the Alaska Peninsula, between False Pass and Thinpoint Cove (Text-figs. 2, 3). The formation was originally defined by Waldron (1961, p. 686) to include strata occurring along 8 km (5 mi) of coastline "from the west end of Thinpoint Cove at least as far west as Cape Tachilni." Waldron (1961) was unable to observe the detailed stratigraphy of these rocks or to map their inland extent, due to the rugged terrain and hazardous landing conditions for the small boats he used. More recent mapping has shown that the formation crops out continuously along the coast west of Cape Tachilni from Morzhovoi Bay to False Pass, and possibly on Deer Island east of Cape Tachilni (McLean, Englehardt, and Howell, 1978; McLean, 1979; Text-fig. 3).

The Tachilni Formation consists mostly of dark brown to light greenish-gray, fine- to coarse-grained sandstone, and abundant similarly colored siltstone, with some pebble conglomerate and black shale (Waldron, 1961; McLean, 1979). The rocks are well bedded and range from semi-consolidated to well-indurated. The sediments are largely of marine origin, but presumably nonmarine clastics containing carbonaceous fragments of plant megafossils occur at some outcrops (Waldron, 1961; McLean, 1979). The sandstone consists mainly of volcanic rock fragments, abrupt facies changes are common, many beds are lenticular, and channels are numerous (Waldron, 1961; McLean, 1979; H. McLean, written commun., 1982). Measurements of trough crossbeds at some Tachilni outcrops suggest bimodal current flow that resulted from tidally influenced environments (H. McLean, written commun., 1982). Tachilni sediments have been extensively intruded by basaltic and silicic dikes, one of which has been radiometrically dated at about 2.1 m.y. (H. McLean, written commun., 1982).

The thickness of the Tachilni Formation is not known, because its base is not exposed. Waldron (1961, p. 686–687) noted "more than 200 feet" of strata near the type locality, and "at least several hundred feet of material . . . exposed along the coast." McLean (1979) reported about 460 m (1,500 ft) of Tachilni strata, in composite section, exposed in coastal bluffs from False Pass to Thinpoint Cove, a straightline distance of about 45 km (28 mi) (Text-fig. 3). In a coastal bluff at the type locality of Cape Tachilni the formation is 75 m (250 ft) thick (Text-fig. 3; H. McLean, written commun., 1982). If strata on Deer Island are assigned to the Tachilni, as questionably mapped by McLean, Englehardt, and Howell (1978) and McLean (1979), then the outcrop area of the formation extends an additional 19 km (12 mi) eastward. Tachilni strata have a low dip at most localities, usually less than 20°, and outcrops are discontinuous due to concealment beneath vege-

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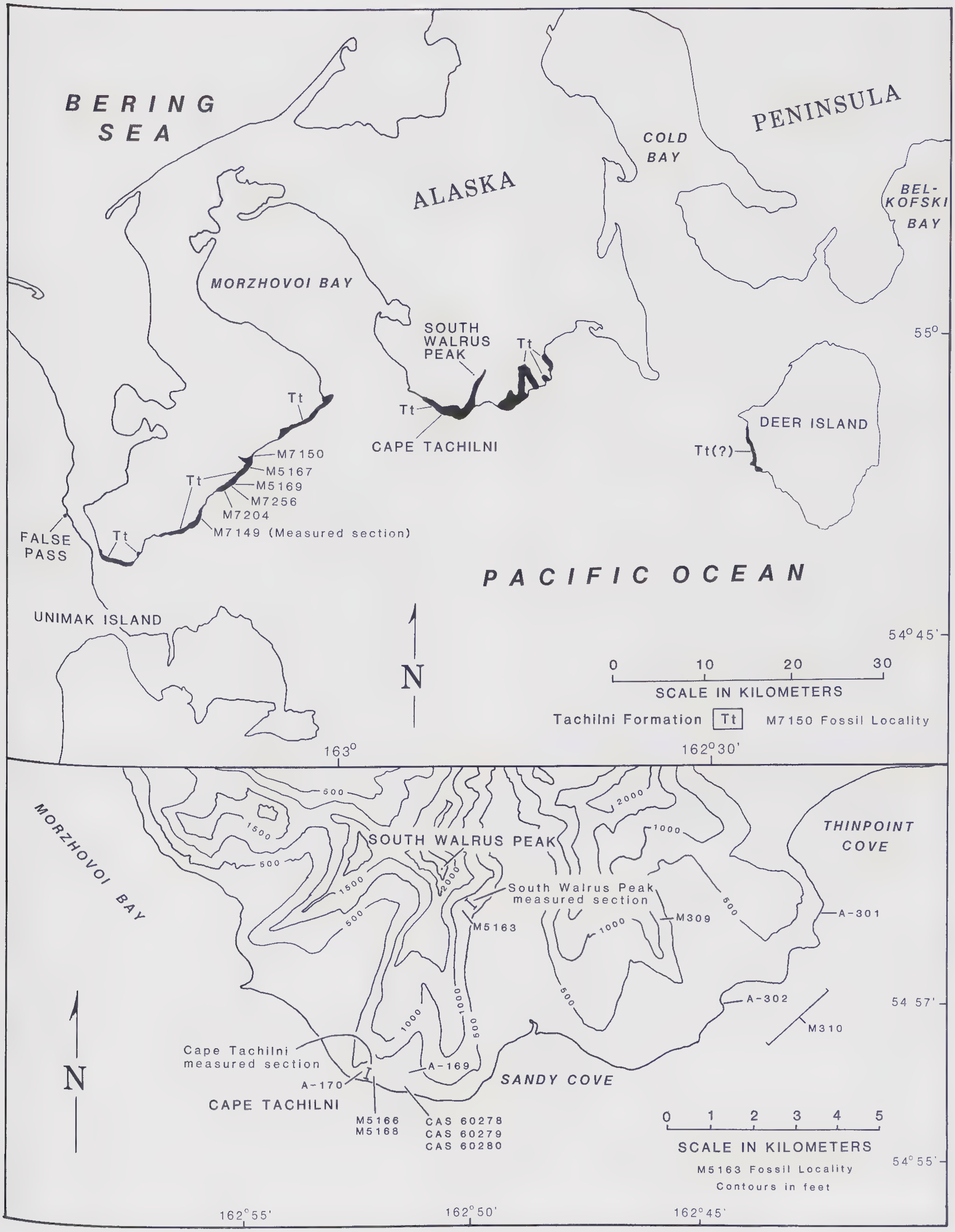
Text-figure 3.—Maps showing location of Tachilni Formation fossil localities and measured sections.


BERING SEA
ALASKA
PENINSULA
COLD BAY
BEL-KOFSKI BAY
MORZHOVOI BAY
SOUTH WALRUS PEAK
Tt
CAPE TACHILNI
DEER ISLAND
Tt(?)
M7150
M5167
M5169
M7256
M7204
M7149 (Measured section)
FALSE PASS
PACIFIC OCEAN
UNIMAK ISLAND
55°
54°45'
0 10 20 30
SCALE IN KILOMETERS
Tachilni Formation Tt
M7150 Fossil Locality
163°
162°30'
THINPOINT COVE
South Walrus Peak measured section
M5163
M309
A-301
A-302
M310
A-169
A-170
Cape Tachilni measured section
M5166
M5168
CAS 60278
CAS 60279
CAS 60280
SANDY COVE
0 1 2 3 4 5
SCALE IN KILOMETERS
M5163 Fossil Locality
Contours in feet
54°57'
54°55'
162°55'
162°50'
162°45'

tation and landslides, so no more than about 250 m (650 ft) of strata occur at a single outcrop.

It is probable that Tachilni strata are disconformably underlain by tuffaceous volcaniclastic rocks of the Belkofski Formation, though a contact between the units has not been observed (H. McLean, written commun., 1982). Belkofski strata are at least 1,800 m (5,900 ft) thick and crop out over a wide area immediately to the northeast of Tachilni terrane (Waldron, 1961; Burk, 1965; McLean, Englehardt, and Howell, 1978; McLean, 1979). Abundant but poorly preserved plant megafossils have suggested a Paleogene age, including estimates as old as Paleocene, for most Belkofski rocks (Burk, 1965). However, a mixed assemblage of deciduous and evergreen leaf fossils suggests an Oligocene age for one Belkofski outcrop on the northwestern shore of Belkofski Bay (McLean, 1979). In addition, an assemblage of four mollusk species, including *Macoma* (*Macoma*) *optiva* (Yokoyama, 1923), collected at a nearby outcrop suggests a Miocene age for part of the formation (Marincovich and McCoy, *in press*). I had previously inferred a probable Oligocene age for this assemblage (*in* McLean, 1979, p. 1522). It is probable that most of Miocene time passed between deposition of the youngest preserved Belkofski rocks and deposition of the Tachilni strata.

The Tachilni Formation is unconformably overlain by Pliocene (?), Pleistocene and Holocene volcanic flows and breccias that cover extensive portions of the Alaska Peninsula in this area (Waldron, 1961; Burk, 1965; McLean, Englehardt, and Howell, 1978; McLean, 1979). In some places the Tachilni Formation forms the modern erosional surface. Waldron (1961, p. 687) noted that the formation "westward . . . appears to pass upward conformably into a basal sequence of nonfossiliferous volcanic sedimentary rocks . . . ," but this gradational upper contact has not been observed by later workers.

FAUNAL COMPOSITION

There are 53 molluscan taxa in the Tachilni fauna: 36 bivalves (68%) and 17 gastropods (32%) [Table 1]. A similarly high ratio of bivalve to gastropod species is evident in many Tertiary mollusk faunas of the Gulf of Alaska region, based on unpublished data from U.S. Geological Survey collections. Kanno (1971, p. 13) documented the high percentages of bivalves in lower and middle Tertiary faunas of the Cape Yakataga area in the northeastern Gulf of Alaska (Text-fig. 1), including faunas of the Kulthieth (upper Paleocene and Eocene), Poul Creek (upper Eocene and Oligocene) and Yakataga (lower Miocene to Pleistocene) Formations. Considered together, these three formations were found to have mollusk faunas of about two-thirds bivalves and one-third gastropods (Kanno, 1971), as does the Tachilni fauna. The only documented exception to this general relationship is the late Oligocene or earliest Miocene fauna of the Narrow Cape Formation on Sitkinak Island in the western Gulf of Alaska (Text-fig. 1). The mollusk fauna there is nearly equally divided among bivalves and gastropods, with 22 bivalves, 20 gastropods, one cephalopod, and one scaphopod (Allison and Marincovich, 1981). Surprisingly, for the modern northeastern Pacific mollusk fauna, the proportion of bivalves to gastropods is the reverse of that seen in most Alaskan Tertiary faunas. Schenck and Keen (1936, p. 937) studied the numbers and kinds of mollusks present within each five-degree increment of latitude from 25°N to 74°N in the eastern Pacific, and showed that for the interval of 55° to 59°N (the modern Gulf of Alaska) only 140 bivalve species were present compared to 343 gastropods and scaphopods (scaphopods constitute a minor element and were not treated separately). Similarly high proportions of gastropods were observed in all other latitudes of this vast study area by Schenck and Keen (1936). Whatever the reason for the predominance of gastropod species in the modern northeastern Pacific, the apparent dominance of bivalves in Alaskan Tertiary faunas is equally enigmatic. A number of Alaskan Tertiary faunas with high percentages of bivalves have been intensively collected by trained paleontologists, so collecting bias probably is not a major factor. If there is a geologic, rather than biologic or environmental, reason for the different proportions of bivalves and gastropods in Tertiary and Holocene faunas of southern Alaska, it probably is related to fossil preservation. Virtually all Tertiary strata in southern Alaska have been subjected to strong tectonic forces, and many also have been thermally altered by deep burial or by igneous or volcanic intrusion, or both. As a result, many molluscan fossils seen in outcrop cannot be collected intact because they have been so extensively fractured or otherwise altered. Diagenetic processes may in some way be more destructive to gastropods than to bivalves. In any case, the relative proportion of bivalves to gastropods in the Tachilni fauna is similar to that among most other Alaskan Tertiary faunas.

Twenty-eight of the 36 Tachilni bivalves (78%) are represented by at least one specimen with articulated, closed valves (Table 2). *Lyonsia mooreae* n. sp. and *Mya* (*Mya*) *truncata* Linnaeus, 1758 were also observed in life positions on the outcrop. These facts

strongly imply that the Tachilni mollusk fauna lived at its site of deposition and contains few, if any, species introduced by post-mortem transport.

The most common Tachilni species, those that occur in the greatest numbers and at several localities, are listed in Table 3. These species reflect the relationship seen in the molluscan fauna as a whole (Table 1) in which the Cape Tachilni stratigraphic section contains the greatest species diversity. Species that occur only in the Cape Tachilni section are listed in Table 4, and those that occur only in the South Walrus Peak section are listed in Table 5. These different assemblages from the same formation reflect local environmental differences that prevailed during deposition, as well as a slight age difference between the two stratigraphic sections.

BIOSTRATIGRAPHY

The measured stratigraphic sections with the most fossiliferous beds are those at Cape Tachilni and South Walrus Peak (Text-fig. 4). If the dips and strikes measured at Cape Tachilni by McLean, Englehardt, and Howell (1978) prevail throughout the intervening 4.5-km (2.7-mi) distance to South Walrus Peak, then the base of the South Walrus Peak section would be about 1 km (3,280 ft) stratigraphically higher than the top of the measured section at Cape Tachilni. However, most of the terrain between these measured sections is covered by vegetation, and the presence of faulting and folding within this covered interval is likely, considering the tectonically active nature of this region. McLean (1979) reported only about 460 m (1,500 ft) of Tachilni Formation exposed throughout its outcrop area. Whatever the precise geometric relations between the South Walrus Peak and Cape Tachilni stratigraphic sections, field relations suggest that the former section is stratigraphically higher than the latter one.

Table 2.—Tachilni Formation bivalves found with articulated and closed valves. Asterisks (*) indicate taxa represented in collections by 50% or more articulated and closed specimens. Crosses (†) indicate species found in living positions (with long axis of articulated and closed shell oriented normal to bedding and posterior end directed upward).

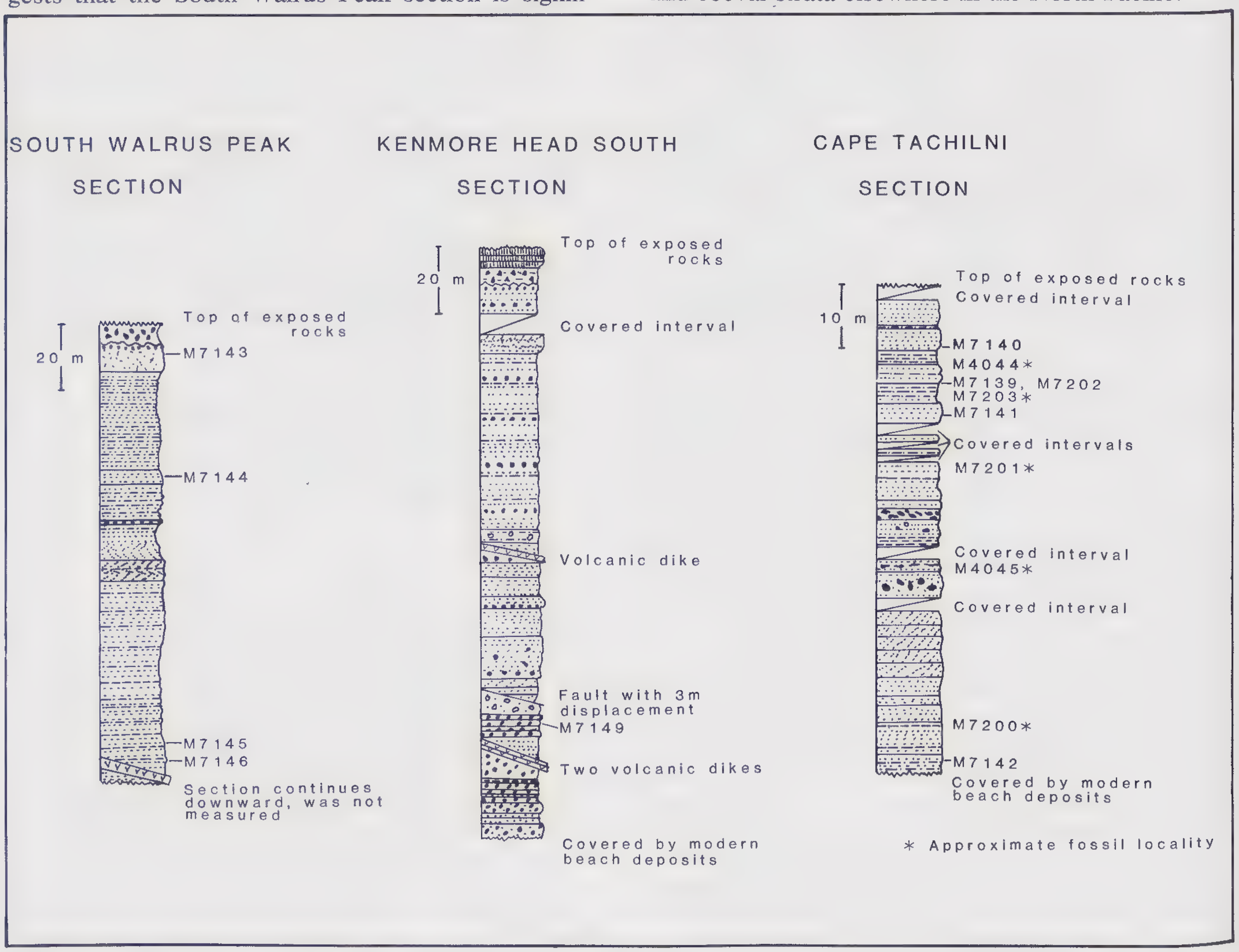
Acila (Truncacila) empirensis
Chlamys (Swiftopecten) cosibensis cosibensis
Clinocardium hannibali
Clinocardium meekianum new subsp.?
**Crenomytilus coalingensis*
**Cyclocardia* cf. *C. roundiformis*
**Cyclocardia sakamotoi*
**Cyclocardia* sp. A
**Felaniella parilis*
**Glycymeris grewingki*
†**Lyonsia mooreae*
**Macoma (Macoma)* cf. *M. (M.) astori*
**Macoma (Macoma) optiva*
Musculus (Musculus) niger
**Mya (Arenomya) elegans*
†**Mya (Mya) truncata*
**Mya* new sp.?
**Panomya izumo*
Panomya trapezoidis
**Periploma (Periploma)* cf. *P. (P.) aleutica*
**Peronidia* aff. *P. lutea alternidentata*
Protothaca (Protothaca) staleyi
**Saxidomus* sp.
Siliqua cf. *S. alta*
Spisula (Mactromeris) albaria
Spisula (Mactromeris) brevirostrata
Spisula (Mactromeris) polynyma
**Yoldia (Cnesterium) scissurata*

Table 3.—The most common and abundant Tachilni mollusks.

	Occurrence in measured sections			
	Only at Cape Tachilni	Mostly at Cape Tachilni	Equally in both sections	Only at South Walrus Peak
Bivalves				
Chlamys (Swiftopecten) cosibensis cosibensis	—	X	—	—
Clinocardium hannibali	—	—	—	X
Clinocardium meekianum n. subsp.?	—	X	—	—
Crenomytilus coalingensis	X	—	—	—
Glycymeris grewingki	—	X	—	—
Macoma (Macoma) cf. *M. (M.) astori*	X	—	—	—
Musculus (Musculus) niger	—	—	—	X
Mya (Arenomya) elegans	—	X	—	—
Mya (Mya) truncata	—	—	X	—
Peronidia aff. *P. lutea alternidentata*	—	X	—	—
Spisula (Mactromeris) polynyma	—	—	X	—
Yoldia (Cnesterium) scissurata	—	—	—	X
Gastropods				
Beringius hertleini	—	X	—	—
Natica (Cryptonatica) clausa	—	X	—	—
Neptunea (Neptunea) lyrata altispira	—	X	—	—
Neptunea (Neptunea) sp. D aff. *N. (N.) modesta*	—	X	—	—
Polinices (Euspira) pallidus	—	—	X	—

This relationship is also implied by the differences in faunal composition between the two stratigraphic sections. Table 5 lists the Tachilni species found only in the South Walrus Peak section, including *Musculus* (*Musculus*) *niger* (Gray, 1824), which has not previously been recorded with certainty from Tertiary rocks, and *Bulbus fragilis* (Leach, 1819), known previously only in late Pliocene to Holocene faunas. Both species are absent from the Cape Tachilni section. Other South Walrus Peak species suggestive of a relatively young age include some whose oldest reliable occurrences are in late Miocene faunas, such as *Clinocardium* cf. *C. ciliatum* (Fabricius, 1780), *C. hannibali* (Keen, 1954), *C.* cf. *C. pristinum* (Keen, 1954), *Panomya izumo* Nomura and Hatai, 1939, *Yoldia* (*Cnesterium*) *scissurata* Dall, 1897, and *Oenopota* cf. *O. candida* (Yokoyama, 1926). The absence of all six of these relatively modern species at Cape Tachilni further suggests that the South Walrus Peak section is significantly higher stratigraphically than the Cape Tachilni section.

Some of the mollusks found only at Cape Tachilni (Table 4) suggest that this section is older than that at South Walrus Peak. In contrast to several of the South Walrus Peak species whose oldest occurrences are in late Miocene faunas, Cape Tachilni species such as *Macoma* (*Macoma*) *optiva* (Yokoyama, 1923), *Molopophorus bogachielii* (Reagan, 1909), *Neptunea* (*Golikovia*) *plafkeri* Kanno, 1971, and *Polinices* (*Euspira*) *diabloensis* (Clark, 1915) have their youngest reported occurrences in late Miocene faunas. So, although many of the mollusk species exclusive to the Cape Tachilini section do range into much younger strata, a significant group of species is best known from occurrences in middle Miocene or older faunas, and last appears in rocks of the Tachilni Formation and coeval strata elsewhere in the North Pacific.



Text-figure 4.—Measured stratigraphic sections and fossil localities in the Tachilni Formation. See Appendix for descriptions of collecting localities.

The inferred chronostratigraphic separation between the Cape Tachilni and South Walrus Peak sections cannot yet be quantified. The discovery of open-ocean microfossils in these rocks, so far unsuccessful, or a study of their paleomagnetic stratigraphy, not yet attempted, would be needed to learn the time difference between deposition of the two stratigraphic sections.

No well-defined biostratigraphic zonation has been established within any of the measured sections of the Tachilni Formation. In the lower part of the Cape Tachilni section (locs. M7142 and M7200; Text-fig. 4) there is only one species not found upsection, the late Miocene to Holocene bivalve *Miodontiscus prolongatus* (Carpenter, 1864b). In the middle part of the section (locs. M4045, M7022, and M7141) only the late Miocene to Pliocene or Pleistocene bivalve *Crenomytilus coalingensis* (Arnold, 1909) is found nowhere else at Cape Tachilni. Species found only in the upper part of the section (locs. M7203 to M7140; see Table 1) are: *Acila* (*Truncacila*) *ermani* (Girard, 1843) [stratigraphic range unknown], *Pandora* (*Pandorella*) *grandis* Dall, 1877 [early Miocene (?) and Pliocene or Pleistocene to Holocene], *Saxidomus* sp., and *Polinices* (*Euspira*) *diabloensis* (Clark, 1915) [middle (?) and late Miocene]. The known age-ranges of these taxa are so broad that they are not useful for biostratigraphic zonation at Cape Tachilni.

Taxa found only within a particular stratigraphic interval are more numerous in the South Walrus Peak section than at Cape Tachilni, though they still do not allow well-defined biostratigraphic zonation. Mollusks found only in the lowest part of the South Walrus Peak section (locs. M7145 and M7146; Text-fig. 4) are listed in Table 6.

Taxa found only in the middle part of the South Walrus Peak section (loc. M7144) are *Clinocardium* sp. and *Mizuhopecten mollerensis* (MacNeil, 1967), and mollusks known only from the uppermost part of the section (loc. M7143) are *Bulbus fragilis* (Leach, 1819) and *Polinices* (*Euspira*) *pallidus* (Broderip and Sowerby, 1829). The large disparity in numbers of taxa known only from particular parts of this section is due

Table 4.—Mollusks found only in the Cape Tachilni stratigraphic section.

Bivalves
Acila (*Truncacila*) *ermani*
Crenomytilus coalingensis
Cyclocardia sakamotoi
Cyclocardia sp. A
Felaniella parilis
Lyonsia mooreae
Macoma (*Macoma*) cf. *M.* (*M.*) *astori*
Macoma (*Macoma*) *optiva*
Miodontiscus prolongatus
Mya new sp.?
Pandora grandis
Protothaca (*Protothaca*) *staleyi*
Saxidomus sp.
Gastropods
Calyptraea sp.
Cancellaria? sp.
Molopophorus cf. *M. bogachielii*
Natica (*Tectonatica*) *janthostoma*
Neptunea (*Golikovia*) *plafkeri*
Oenopota sp. A
Polinices (*Euspira*) *diabloensis*

Table 5.—Mollusks found only in the South Walrus Peak stratigraphic section.

Bivalves
Clinocardium cf. *C. ciliatum*
Clinocardium hannibali
Clinocardium cf. *C. pristinum*
Mizuhopecten mollerensis
Musculus (*Musculus*) *niger*
Panomya izumo
Panomya trapezoidis
Yoldia (*Cnesterium*) *scissurata*
Gastropods
Bulbus fragilis
Fusitriton oregonensis
Oenopota cf. *O. candida*

Table 6.—Mollusks found in the South Walrus Peak stratigraphic section, but only at the stratigraphically lowest localities, USGS M7145 and M7146.

Bivalves
Chlamys (*Swiftopecten*) *cosibensis cosibensis*
Clinocardium cf. *C. ciliatum*
Clinocardium hannibali
Clinocardium meekianum new subsp.?
Clinocardium cf. *C. pristinum*
Cyclocardia cf. *C. roundiformis*
Glycymeris grewingki
Macoma incongrua
Musculus (*Musculus*) *niger*
Mya (*Arenomya*) *elegans*
Periploma (*Periploma*) cf. *P.* (*P.*) *aleutica*
Peronidia aff. *P. lutea alternidentata*
Siliqua cf. *S. alta*
Spisula (*Mactromeris*) *albaria*
Spisula (*Mactromeris*) *brevirostrata*
Spisula (*Mactromeris*) *polynyma*
Gastropods
Beringius hertleini
Buccinum cf. *B. planeticum*
Fusitriton oregonensis
Margarites (*Pupillaria*) new sp.?
Natica (*Cryptonatica*) *clausa*
Neptunea (*Neptunea*) sp. D aff. *N.* (*N.*) *modesta*

partly to the richness of the lower fossiliferous beds and partly to the greater amount of time spent collecting from them.

One species previously known only in late Pliocene to Holocene faunas, *Bulbus fragilis,* occurs only in the stratigraphically highest part of the South Walrus Peak section. However, species with no previous records as fossils, such as *Buccinum* cf. *B. planeticum* Dall, 1919, and *Periploma* cf. *P. aleutica* (Krause, 1885), occur at South Walrus Peak only in the stratigraphically lowest collecting localities (Table 6), rather than at the highest localities. With these two relatively youthful species are found taxa known only from Miocene faunas, such as *Clinocardium* cf. *C. pristinum* Keen, 1954, and *Cyclocardia* cf. *C. roundiformis* (Ilyina, 1963). Thus, the stratigraphic occurrences of species in the South Walrus Peak section do not permit recognition of chronostratigraphic zones.

The main hindrance to biostratigraphic zonation within individual Tachilni sections is the thinness of the exposed sections themselves. The section at Cape Tachilni is only 75 m (250 ft) thick, the South Walrus Peak measured section is about 120 m (394 ft) thick (Text-fig. 4), and most other Tachilni sections are thinner. In a region such as the Alaska Peninsula, characterized by high Tertiary sedimentation rates, these relatively thin rock sequences were probably deposited too quickly for the molluscan faunas to have undergone major evolutionary changes.

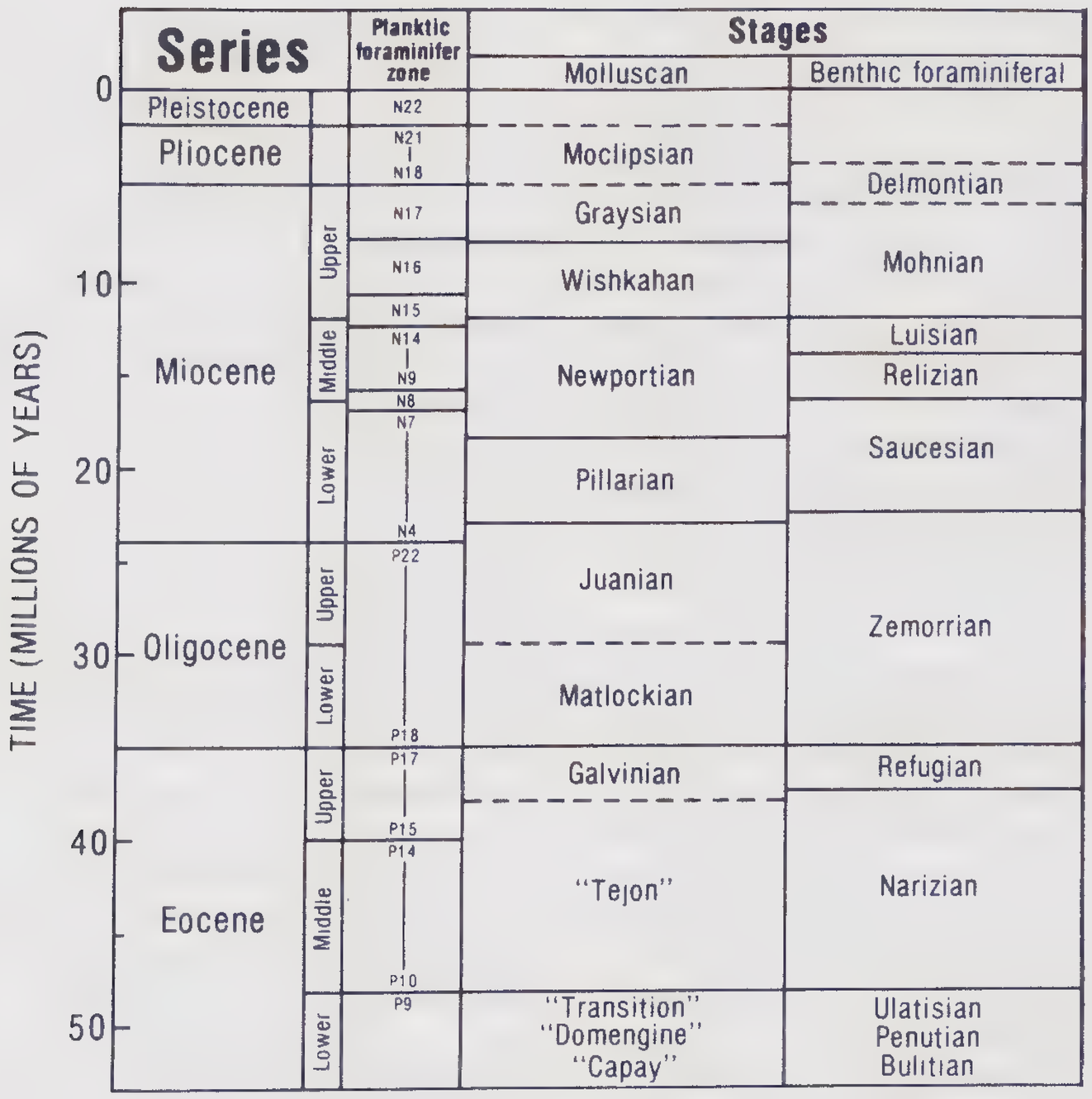
The relative stratigraphic positions of less fossiliferous Tachilni sections and outcrops, such as those southwest of Morzhovoi Bay (Text-fig. 3), are impossible to determine from available data. The most fossiliferous of these localities is M7150, which yielded 20 molluscan taxa (Table 1) and is located 9.6 km (6.0 mi) southwest of the mouth of Morzhovoi Bay. Compared to the faunas of the two main sections, at Cape Tachilni and South Walrus Peak, the fauna at locality M7150 contains four species found only at Cape Tachilni [*Macoma* (*Macoma*) cf. *M.* (*M.*) *astori* Dall, 1909, *M.* (*M.*) *optiva* (Yokoyama, 1923), *Molopophorus bogachielii* (Reagan, 1909), and *Natica* (*Tectonatica*) *janthostoma* Deshayes, 1839], four found at South Walrus Peak [*Acila* (*Truncacila*) cf. *A.* (*T.*) *empirensis* Howe, 1922, *Clinocardium hannibali* Keen, 1954, *Mizuhopecten mollerensis* (MacNeil, 1967), and *Oenopota* cf. *O. candida* (Yokoyama, 1926)], and 12 species found at both major sections. Thus, the fauna at locality M7150 does not show a preferred correlation with either the section at Cape Tachilni or the somewhat younger South Walrus Peak section. In addition, the fauna at locality M7150 contains both species whose youngest occurrences are in late Miocene faunas and species whose oldest occurrences are in late Miocene faunas, so there is no basis for inferring a relationship with older or younger parts of the Neogene.

A similar situation prevails for other localities southwest of Morzhovoi Bay, including M7256 (with 11 taxa), M7149 (with eight taxa), and others containing even fewer taxa (Table 1). Difficulties in correlating these faunas with those at Cape Tachilni and South Walrus Peak are mainly due to diagenetic alteration of fossils southwest of Morzhovoi Bay. The common intrusion of plutonic rocks in the latter area has not only destroyed much of the original fauna, but made the surviving specimens more difficult to identify. However, all of the species found southwest of Morzhovoi Bay occur in the faunas at Cape Tachilni and South Walrus Peak, so they support the conclusion of McLean, Englehardt, and Howell (1978) and McLean (1979) that strata southwest of Morzhovoi Bay should be included in the Tachilni Formation.

AGE AND CORRELATION

The Tachilni molluscan fauna correlates well with late Miocene faunas of the North Pacific region, especially with those assigned to the Wishkahan Stage of Oregon and Washington. Tachilni mollusks with reliable records only in strata of late Miocene age are *Clinocardium* cf. *C. pristinum* (Keen, 1954) [from the San Pablo Group of northern California], *Crenomytilus coalingensis* (Arnold, 1909) [from central and southern California], and *Polinices* (*Euspira*) *diabloensis* (Clark, 1915) [from northern and central California]. Other Tachilni mollusks have their first or last known occurrences in faunas of late Miocene age. Taxa known only in late Miocene or older rocks are *Macoma* (*Macoma*) *optiva* (Yokoyama, 1923) [from early to late Miocene faunas of Asia], and *Cyclocardia* cf. *C. roundiformis* (Ilyina, 1963) [from middle (?) to upper Miocene strata of Asia]. In addition, the two large-shelled, few-ribbed Tachilni species of *Cyclocardia*, *C. sakamotoi* n. sp. and *Cyclocardia* sp. A, belong to a group of similar Asian species of *Cyclocardia* known only in upper Miocene strata. In contrast, the following taxa have their oldest known occurrences in late Miocene faunas: *Miodontiscus prolongatus* (Carpenter, 1864b) [from central California and Kamchatka], *Musculus* (*Musculus*) *niger* (Gray, 1824) [from eastern Kamchatka], and *Oenopota* cf. *O. candida* (Yokoyama, 1926) [from southern Sakhalin]. Taken together, the 11 taxa noted above comprise about 21% of the Tachilni fauna.

A possible early Pliocene age for all or part of the Tachilni Formation stratotype, as postulated by MacNeil *et al.* (1961), MacNeil (1970), and Wagner



Text-figure 5.—Correlation of Pacific Northwest molluscan stages with foraminiferal stages [from Addicott (1981)].

(1974), is refuted by the presence of so many mollusks that suggest a late Miocene age, and by the lack of any early Pliocene indicators. Tachilni strata are somewhat older than thought by Allison (1977, 1978), who referred the formation to the latest Miocene and stated that the Miocene–Pliocene boundary might fall somewhere within it. Marincovich (*in* McLean, Englehardt, and Howell, 1978) and McLean (1979) cited a late Miocene or Pliocene age for Tachilni mollusks, though after further study Marincovich (1981b) inferred an early late Miocene age for the fauna.

Assignment of the Tachilni fauna to the Wishkahan Molluscan Stage of Oregon and Washington (Text-fig. 5) is suggested by several taxa. The Tachilni bivalves *Clinocardium hannibali* Keen, 1954 and *Glycymeris grewingki* Dall, 1909 are found in Oregon and Washington only in Wishkahan faunas (Addicott, 1976a), and the bivalves *Felaniella parilis* (Conrad, 1848) and *Macoma* (*Macoma*) *astori* Dall, 1909 [the latter only tentatively recognized in the Tachilni fauna] have their stratigraphically highest occurrences in Wishkahan faunas of the same region (Addicott, 1976a). The latter two species are difficult to identify with certainty, so their use in making age inferences is limited. A large number of Tachilni mollusks have their earliest occurrences in the Pacific Northwest in Wishkahan faunas, including: *Acila* (*Truncacila*) *empirensis* Howe, 1922, *Protothaca* (*Protothaca*) *staleyi* (Gabb, 1866), *Yoldia* (*Cnesterium*) *scissurata* Dall, 1897, and *Molopophorus bogachielii* (Reagan, 1909), and the genera *Clinocardium* Keen, 1936, *Mizuhopecten* Masuda, 1963 and *Siliqua* Megerle von Muehlfeld, 1811 (Addicott, 1976a). Based on their first, last, or exclusive appearance in Wishkahan faunas of the Pacific Northwest, the 11 Tachilni taxa cited above, making up about 21% of the fauna, strongly suggest a Wishkahan age for Tachilni strata.

Age assignments for the six Miocene and Pliocene molluscan stages proposed for Oregon and Washington by Addicott (1976a) were based largely on the inferred chronostratigraphic ranges of numerous mollusks, with modest supporting evidence from benthic and planktonic foraminifers and radiometric dates. The Wishkahan Stage was considered to be of early late Miocene age. However, closely drawn ties between the molluscan faunas upon which the stages were based and radiometrically well-dated planktonic microfossils were not made. The Wishkahan Stage was interpreted differently by Allison (1977, 1978), who considered it to be of late middle Miocene to early late Miocene

age. His conclusions were based on an attempted correlation between Pacific Northwest molluscan faunas, benthic foraminiferal stages of southern and central California, and the modern planktonic foraminiferal zones of Berggren and Van Couvering (1974). This interpretation was used for southern Alaskan faunas by McCoy and Marincovich (1980) and Marincovich (1980, 1981b). A recent restatement by Addicott (1981) of an exclusively early late Miocene age for the Wishkahan is based on implied, but undocumented, ties with planktonic foraminifers (Text-fig. 5). To date, no systematic study of planktonic microfossil occurrences in the Pacific Northwest molluscan stages has been attempted, and the relationship of the stages to sub-epoch boundaries is uncertain.

Recent studies of diatom biostratigraphy in Pacific Northwest Miocene strata have created uncertainty about the age of the Wishkahan Stage and its relationship to the Graysian Stage. The type section of the Wishkahan Stage consists of the lowermost one-third, or 300 m (985 ft), of the Montesano Formation of Fowler (1965) exposed along the west fork of the Wishkah River, southwestern Washington (Addicott, 1976a, p. 105). The Graysian Stage stratotype is the conformably overlying two-thirds of the Montesano Formation exposed nearby along the middle fork of the Wishkah River, and was considered to be of late late Miocene age by Addicott (1976a). Armentrout (1981) has tentatively suggested that the Wishkahan and Graysian Stages are fully coeval and may include the latest middle Miocene and earliest Pliocene as well as the late Miocene. His conclusions were based on diatom floras recovered from the type Graysian section in the upper Montesano Formation (Barron, 1981), and from strata of the Empire Formation at Coos Bay, Oregon (Barron and Armentrout, 1980), assigned to the Wishkahan by Addicott (1976a). These diatom studies suggest that the stratotype of the Graysian Stage is of early late Miocene age and that Empire Formation strata assigned to the Wishkahan by Addicott (1976a) are of middle late Miocene age. Diatoms of the type Wishkahan have not been studied, but the likelihood is that the Wishkahan and Graysian Stages may be at least in part coeval. The overlap, if any, of the two molluscan stages has not been determined.

According to mega- and microfossil evidence summarized by Armentrout (1981), the base of the Wishkahan Stage is questionably placed at about 12 m.y. old, or slightly older than the beginning of the late Miocene. The top of the Graysian Stage is placed by Armentrout (1981) at slightly less than 5 m.y. old, or virtually the same as the 5 m.y. age originally assigned to this boundary by Addicott (1976a). If the Wishkahan and Graysian are coeval, the top of the Wishkahan would also be at 5 m.y. or slightly younger. However, if Addicott's (1976a) original estimate is correct, the top of the Wishkahan is about 7.5 m.y. old, as suggested more recently by Addicott (1981). In the present study of Tachilni mollusks, the Wishkahan is considered to range from about 7.5 to 12 m.y. B.P. and to be of early late Miocene age. During the present study, Tachilni samples were barren of benthic foraminifers (K. McDougall, oral commun., 1978), and lacked age-diagnostic diatoms (J. Barron, oral commun., 1982).

The geographically closest strata correlative with the Tachilni Formation are those of the Bear Lake Formation, which crops out on the distal half of the Alaska Peninsula, to the northeast of Cape Tachilni (Text-fig. 2). Based on unpublished studies of the Bear Lake Formation by U.S. Geological Survey and petroleum company paleontologists, its molluscan fauna is known to be at least as diverse as that of the Tachilni. Allison (1978, p. 175) noted that "A megainvertebrate fauna of about 40 species is known from the Bear Lake Formation above the Unga Conglomerate and below the unconformably overlying strata." The fauna is now known to be much larger. As an example of the disparity between published and unpublished knowledge of the Bear Lake fauna, MacNeil (*in* Burk, 1965, p. 228) noted seven molluscan species from the Bear Lake stratotype, whereas I have collected about 25 species from the same beds. The biostratigraphy of the Bear Lake is poorly known because the inaccessibility of outcrops and extremely poor weather in the region have restricted collecting activities. Extensive faulting and coverage by tundra vegetation and late Cenozoic volcanic debris have also complicated study of the Bear Lake rocks. The Bear Lake molluscan fauna was described by Allison (1977, 1978) as "warm temperate," but this may be untrue for the bulk of the fauna, which is similar in its inferred paleotemperature to the Tachilni fauna. Inferred warm temperate molluscan genera noted by Allison (1978, p. 175) possibly occur in one or more stratigraphically limited zones, and not generally throughout the Bear Lake sequence. The Tachilni Formation is correlative with the unnamed upper member of the Bear Lake Formation, with which it shares at least the 23 taxa listed in Table 7.

The faunal relationship between the Tachilni and the basal Unga Conglomerate Member of the Bear Lake Formation is much less certain, because fossils from the latter unit are very poorly known (MacNeil, 1973; Allison, 1978). Only two Tachilni mollusks, *Chlamys* (*Swiftopecten*) *cosibensis cosibensis* (Yokoyama, 1911) and *Mizuhopecten mollerensis* (MacNeil, 1967), are

known to occur in collections from the Unga Conglomerate. The latter unit was inferred to be of early Miocene age by MacNeil (1973) and of latest early Miocene to middle Miocene age by Allison (1977, 1978), so substantial faunal differences from the Tachilni molluscan fauna are expectable.

In the vicinity of Black Peak, about 320 km (200 mi) northeast of Cape Tachilni (Text-fig. 2), strata said to unconformably overlie the upper part of the Bear Lake Formation were correlated with the Tachilni Formation by Allison (1978, p. 175). Other workers had noted the presence of late Miocene mollusks in these beds (MacNeil *et al.*, 1961, annotation 3a) and had assigned them to the Bear Lake Formation (Burk, 1965; Detterman, Yount, and Case, 1981) without recognizing a local unconformity. Allison (1978) gave no list of mollusks from the strata near Black Peak, and the 15 taxa reported from there by Marincovich (*in* Detterman, Yount, and Case, 1981) provide no firm basis for formational assignment. Further study of the Bear Lake molluscan fauna in the vicinity of Black Peak is under way. Coarse volcaniclastic beds unconformably overlying the Bear Lake Formation near its type locality, about 200 km (120 mi) northeast of Cape Tachilni, were thought to be of Pliocene age by Burk (1965, p. 94) and were referred to the Tachilni Formation by Allison (1978, p. 175). Meager field investigations in this area have so far produced no fossils that are unquestionably from these volcaniclastic beds. These strata, which are about 1,525 m (5,000 ft) thick at their type locality and are largely of nonmarine origin, were named the Milky River Formation by Galloway (1974, p. 381, 384) and formally defined by Detterman, Yount, and Case (1981). A volcanic flow near the top of the Milky River Formation has been dated at 3 m.y. (Wilson *in* Detterman, Yount, and Case, 1981). The Milky River Formation may be younger than the Tachilni Formation, but learning its exact age and stratigraphic relationship to the latter unit will depend on future studies.

A tenuous correlation between Tachilni strata and presumed upper Miocene beds on Atka Island, in the Aleutian Islands (Text-fig. 1), is based on the co-occurrence of a single distinctive species, *Acila* (*Truncacila*) *ermani* (Girard, 1843). This species is reliably known only from its type locality in unnamed beds on Atka Island (Girard, 1843), from the Tachilni Formation, and from the Bear Lake Formation near Bear Lake (Text-figs. 1, 2). The very limited occurrence of this species suggests a possible correlation between the beds on Atka Island and those on the Alaska Peninsula. The Tertiary fauna on Atka Island has not been recollected since its original mention by Girard (1843).

The Tachilni fauna is more confidently correlated with part of the Yakataga Formation near Cape Yakataga in the northeastern Gulf of Alaska (Text-fig. 1). The contact between the Yakataga Formation and underlying Poul Creek Formation is time-transgressive, ranging in age from about latest Oligocene or early Miocene to early middle Miocene (Ariey, 1978; Addicott, Winkler, and Plafker, 1978; Allison, 1978), or from earliest early Miocene to late Miocene (McCoy and Marincovich, 1980). Wishkahan faunas have been recognized in numerous Yakataga Formation strati-

Table 7.—Tachilni mollusks also found in the unnamed upper member of the Bear Lake Formation, Alaska Peninsula. Based on specimens in U.S. Geological Survey collections.

Bivalves
Acila (*Truncacila*) *empirensis*
Acila (*Truncacila*) *ermani*
Chlamys (*Swiftopecten*) *cosibensis cosibensis*
Clinocardium cf. *C. ciliatum*
Clinocardium meekianum new subsp.
Felaniella parilis
Macoma (*Macoma*) cf. *M.* (*M.*) *astori*
Macoma incongrua
Mizuhopecten mollerensis
Mya (*Arenomya*) *elegans*
Mya (*Mya*) *truncata*
Peronidia aff. *P. lutea alternidentata*
Siliqua cf. *S. alta*
Spisula (*Mactromeris*) *polynyma*
Yoldia (*Cnesterium*) *scissurata*
Gastropods
Buccinum cf. *B. planeticum*
Margarites (*Pupillaria*) new sp.?
Natica (*Cryptonatica*) *clausa*
Natica (*Tectonatica*) *janthostoma*
Neptunea (*Neptunea*) *lyrata altispira*
(?) *Neptunea* (*Golikovia*) *plafkeri*
Polinices (*Euspira*) *pallidus*

Table 8.—Tachilni mollusks also found in presumed Wishkahan faunas of the Yakataga Formation. Asterisks (*) indicate taxa with first or last occurrences in Wishkahan faunas.

Bivalves
**Acila* (*Truncacila*) *empirensis*
Chlamys (*Swiftopecten*) *cosibensis cosibensis*
Clinocardium ciliatum
Felaniella parilis
Macoma (*Macoma*) cf. *M.* (*M.*) *astori*
Mya (*Arenomya*) *elegans*
Mya (*Mya*) *truncata*
**Saxidomus* sp.
**Siliqua* cf. *S. alta*
Spisula (*Mactromeris*) *polynyma*
Gastropods
Fusitriton oregonensis
Natica (*Cryptonatica*) *clausa*
**Neptunea* (*Neptunea*) *lyrata altispira*
**Neptunea* (*Golikovia*) *plafkeri*
Polinices (*Euspira*) *pallidus*

Table 9. Occurrences of Tachilni mollusks in some Miocene strata of the northeastern Pacific. 1 = taxon is known only in this stage; 2 = taxon has first occurrence in this stage; 3 = taxon has last occurrence in this stage.

	PACIFIC NORTHWEST MOLLUSCAN STAGES						CALIFORNIA UPPER MIOCENE STRATA		
	NEWPORTIAN	WISHKAHAN				GRAYSIAN			
	Astoria Fm., NW Oregon (Newportian stratotype)	Empire Fm., SW Oregon	Montesano Fm., lower part, SW Washington (Wishkahan stratotype)	Quillayute Fm., NW Washington	Skonun Fm., British Columbia, Canada	Montesano Fm., middle and upper parts, SW Washington (Graysian stratotype)	Etchegoin Fm., Central Calif.	Santa Margarita Fm., Central Calif.	Neroly Fm., Northern Calif.
Bivalves									
Acila (Truncacila) empirensis		2	2	2	—	X	—		
Clinocardium	—	—	2		—	—	—	—	—
Clinocardium hannibali	—	—	1	—		—	—		
Clinocardium meekianum, s.l.	—	2	—	—	—	—	—	—	—
Clinocardium pristinum	?	–	—	—	—	—	—	–	X
Crenomytilus coalingensis	—	—	—	—	—	—	X	—	
Felaniella parilis	—	3	3						
Glycymeris grewingki	—	1	—	—	1				
Macoma (Macoma) cf. *M.(M.) astori*	—	3	—		—	—	—		
Macoma (Macoma) optiva	X	—	—	—	—	—			
Mizuhopecten	—	—	2	—		3	–		
Mya	—	—	2	—	—	—	—	–	
Protothaca		—	2		2		—	–	
Protothaca (Protothaca) staleyi		3	–	—	—		X		
Siliqua	—	2	2	—	2	—	—		
Siliqua cf. *S. alta*	—	—	—	—	—	–	X		
Spisula (Mactromeris) albaria	X	–	—	X					
Spisula (Mactromeris) brevirostrata	X	X							
Yoldia (Cnesterium) scissurata	—	—	—	—		2			
Gastropods									
Buccinum	—	—	2						
Fusitriton	—	—	2						
Fusitriton oregonensis	–	X							
Molopophorus cf. *M. bogachielii*	—	2	—	2	2	3			
Natica (Tectonatica) janthostoma	—	2	2	—	2				
Neptunea	—	2	2						
Polinices (Euspira) diabloensis	—		—	—	—		—	X	X
Polinices (Euspira) pallidus	—	—	—	—	–	—	X		

graphic sections (Ariey, 1978; Addicott, Winkler, and Plafker, 1978), including the well-known section at Cape Yakataga (Text-fig. 1), where the first Wishkahan mollusks occur about 30 m (100 ft) above the base of the section (Ariey, 1978). The thickness of Wishkahan-age strata in the Yakataga Formation is not known, due to the lack of detailed biostratigraphic studies, but thicknesses of 300 m (1,000 ft) or more are implied by some of the stratigraphic sections figured by Addicott, Winkler, and Plafker (1978).

Tachilni mollusks found in presumed Wishkahan faunas of the Yakataga Formation are listed in Table 8. Among these 15 taxa, five have their first or last known occurrences in Wishkahan faunas: *Acila* (*Trun-*

Table 10. Occurrences of Tachilni mollusks in some Asian Miocene strata.

	WESTERN KAMCHATKA					NORTH SAKHALIN	SOUTH SAKHALIN	KURIL ISLANDS		
	KAVRAN GROUP			VAYAMPOL GROUP						
	Kakert Fm.	Etolon Fm.	Erman Fm.	Kuluven Fm.	Nutovo Fm.	Maruyama Fm.	Kamuyska Fm.	Alekhinska Fm.	Okeanska Fm.
Bivalves									
Chlamys (Swiftopecten) cosibensis cosibensis	X	X	—	—	X	X	X	—	X
Clinocardium ciliatum		—	—	—	—	X	X	X	
Crenomytilus coalingensis	—	—	X	—					
Cyclocardia cf. *C. roundiformis*	—	X		—	—	—	—	—	—
Felaniella parilis	X	X	—						
Glycymeris grewingki	X		—	—	—	—		—	
Macoma (Macoma) optiva	X	X	—	X	—	X	X	X	
Miodontiscus prolongatus	—	X		—		—	—	—	—
Mya (Mya) truncata	X	X	—	X					
Pandora (Pandorella) grandis	—	—	—	X			—		—
Protothaca (Protothaca) staleyi	—	—	X	—					
Spisula (Mactromeris) brevirostrata		X	—		—		—		
Spisula (Mactromeris) polynyma	X	X	—	—	—	—	—	—	X
Gastropods									
Natica (Cryptonatica) clausa	X	X	—	—	—				
Natica (Tectonatica) janthostoma	—	X							
Neptunea (Neptunea) lyrata, s.l.		X	—	—	—		—	—	
Oenopota cf. *O. candida*		—	—	—	X				

cacila) *empirensis* Howe, 1922, *Saxidomus* Conrad, 1837, *Siliqua* Megerle von Muehlfeld, 1811, *Neptunea* (*Neptunea*) *lyrata altispira* (Gabb, 1869), and *Neptunea* (*Golikovia*) *plafkeri* Kanno, 1971. With the exception of *N.* (*G.*) *plafkeri*, these taxa help to tie the Tachilni fauna to the relatively poorly known Yakataga fauna as well as to the much better known faunas of Oregon and Washington. The number of species found in both the Tachilni and Yakataga Formations may increase as the fauna of the latter unit becomes better known. However, probably in number of taxa and certainly as a percentage of their total fauna, Tachilni mollusks will probably remain better represented in the Bear Lake Formation than in the Yakataga Formation. This is due not only to the greater geographic proximity of the Bear Lake fauna to the Tachilni fauna, but also to the faunal provincialism that had developed in southern Alaska by the late Miocene. Tachilni and Bear Lake molluscan faunas during the Wishkahan existed in a warmer marine climate than did the coeval glaciomarine Yakataga fauna.

Despite the great geographic distance between the Alaska Peninsula and the Pacific Northwest (Text-fig. 1), the two areas shared a similar marine climate during the late Miocene and had a number of molluscan taxa in common. The strongest Tachilni faunal ties are with the fauna of the type Wishkahan Stage in the lower part of the Montesano Formation of southwestern Washington, and with other Wishkahan faunas in Washington, Oregon, and British Columbia, Canada (Table 9). One of these listed Tachilni species, *Clinocardium hannibali* Keen, 1954, was known previously only in Montesano Formation Wishkahan faunules. Most of the taxa listed in Table 9 have their earliest known occurrences in the Pacific Northwest in faunas of Wishkahan age, based on the observations

of Addicott (1976a), which suggests that the Tachilni strata are not significantly older than the lower part of the Montesano Formation.

The presence of several Tachilni species in Wishkahan faunas of the Empire, Quillayute and Skonun Formations (Table 9) reinforces the inferred Wishkahan age of the Tachilni fauna and its correlation with the fauna in the lower part of the Montesano Formation. The lesser number of Tachilni mollusks in the type Newportian fauna of the Astoria Formation, and in the type Graysian fauna of the middle and upper parts of the Montesano Formation, reinforces the Wishkahan age inferred for the Tachilni fauna.

Among the few Tachilni species that occur as far south as California (Table 9), *Clinocardium pristinum* Keen, 1954 and *Polinices* (*Euspira*) *diabloensis* (Clark, 1915) are notable in that the former is known only in the Neroly Formation and the latter is an uncommon species previously known only in a few upper Miocene faunas of California, including those in the Neroly and Santa Margarita Formations. On the meager evidence provided by these two species, the Neroly Formation of northern California is tentatively considered to be correlative with the Tachilni Formation.

More than one-third of the Tachilni molluscan taxa also occur in Asian Miocene faunas, as shown in Tables 10 and 11. The closest faunal ties are with the Etolon Formation of the Kavran Group in western Kamchatka, which contains eleven Tachilni taxa. The Etolon molluscan fauna has been referred to the late middle Miocene in recent Russian works (Menner, Baranova, and Zhidkova, 1977; Gladenkov, 1977). However, Menner, Baranova, and Zhidkova (1977, table 1) show the Etolon to be about 7 to 12 m.y. old, which coincides closely with the age of the Wishkahan Stage, assigned to the early late Miocene by other workers (Addicott, 1977, 1981). The Etolon Formation is considered here to be of early late Miocene age, roughly coeval with the Tachilni Formation. Ilyina (1963, p. 15–16) recognized 109 species-level molluscan taxa in the Etolon fauna. Her species lists indicate a more thermally diverse fauna than I have inferred for the smaller Tachilni fauna. The Etolon fauna contains taxa indicative of both cooler and warmer water than are present in the Tachilni fauna. As shown in Table 10, the Etolon Formation has more species in common with the Tachilni Formation than do the underlying Kakert Formation or the overlying Erman Formation of western Kamchatka.

The Tachilni bivalve species *Cyclocardia sakamotoi* n. sp., though not known in Asia, suggests by its size and sculpture a tie with the Etolon fauna. Large, few-ribbed Tertiary species of *Cyclocardia* such as *C. etalonnensis* (Slodkewitsch, 1935) and *C. kavranensis* (Slodkewitsch, 1935), have been reported previously only from the Etolon Formation (Slodkewitsch, 1935, 1938a, 1938b; Ilyina, 1963). One other bivalve, tentatively identified in the Tachilni fauna as *Cyclocardia roundiformis* (Ilyina, 1963), also has been reported previously only in the Etolon (Ilyina, 1963). Another species, *Miodontiscus prolongatus* (Carpenter, 1864b), has its oldest Asian record in the Etolon fauna. On the other hand, *Protothaca* (*Protothaca*) *staleyi* (Gabb, 1866) is reported from Russia only in the Erman Formation (Gladenkov, 1977), which overlies the Etolon strata, consists largely of nonmarine deposits (Ilyina, 1963), and is of about late late Miocene age.

The Kakert Formation of western Kamchatka underlies the Etolon, is of about late middle Miocene age, and has seven species in common with the Tachilni strata (Table 10). The presence of so many Tachilni species in this middle Miocene Asian unit [compared to only three Tachilni taxa in the upper upper Miocene Erman Formation] suggests an affinity of the Tachilni fauna with older Miocene faunas, rather than with faunas of the latest Miocene.

Correlation of the Tachilni fauna with other Asian Miocene faunas is difficult because few Tachilni species occur in Sakhalin, the Kuril Islands and Japan. As seen in Table 10, three Tachilni species occur in the Maruyama Formation of southern Sakhalin, two are known in the Nutovo Formation of northern Sakhalin, and similarly small numbers of species occur in formations on the Kuril Islands. The only previous report of the common Tachilni bivalve species *Musculus* (*Musculus*) *niger* (Gray, 1824) in a Miocene fauna is that of Ilyina (1963) from the upper Miocene Konstantin Formation of eastern Kamchatka. These Asian faunas might be coeval with the Tachilni fauna, but further study of them would be required to determine this.

Well-founded correlations with Japanese formations are prevented by the rarity of species in common with the Tachilni fauna. Tachilni mollusks known in Jap-

Table 11.—Tachilni mollusks found in Japanese Miocene faunas.

Bivalves
Chlamys (*Swiftopecten*) *cosibensis cosibensis*
Clinocardium cf. *C. ciliatum*
Macoma (*Macoma*) *optiva*
Mizuhopecten sp.
Mya (*Mya*) *truncata*
Panomya izumo
Spisula (*Mactromeris*) *polynyma*
Gastropod
Oenopota cf. *O. candida*

anese Miocene faunas are listed in Table 11. Their stratigraphic occurrences, cited under individual systematic entries herein, are widely scattered and provide no firm basis for correlating individual Japanese formations with the Tachilni strata.

Many Miocene mollusks probably occur in both Hokkaido and Alaska, but direct comparative studies of species from these two areas have not yet been done. Species not listed in Tables 10 and 11, including *Lyonsia mooreae* n. sp., *Mizuhopecten mollerensis* (MacNeil, 1967), and *Peronidia* aff. *P. lutea alternidentata* (Broderip and Sowerby, 1829), are clearly of Asian affinities and suggest that detailed species comparisons between Asian and Alaskan faunas will yield refined faunal correlations.

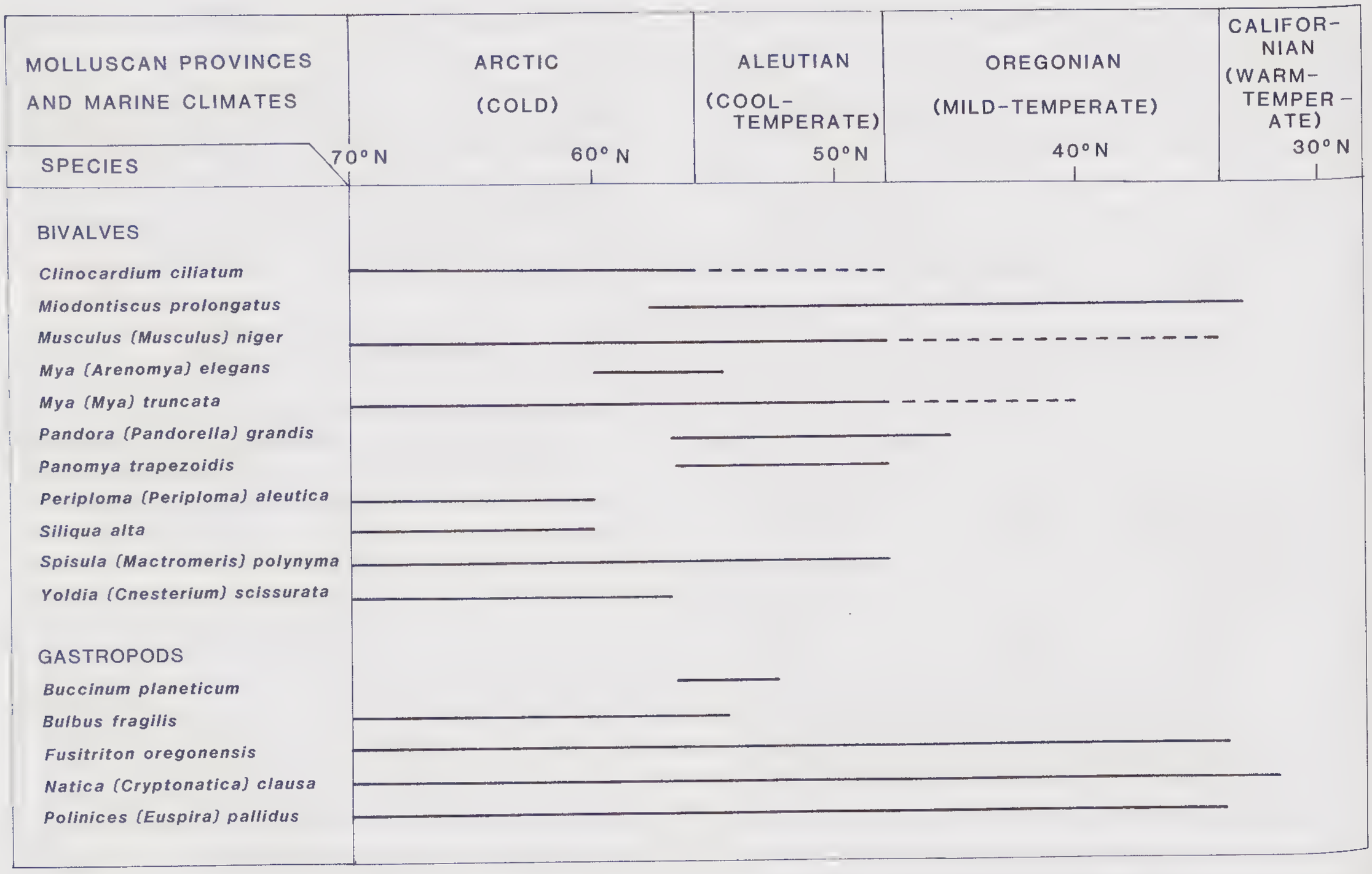
In general composition the Tachilni fauna is analogous to the cold-water, sandy substrate fauna of the upper Miocene Kurosawa Formation of northeastern Honshu (Hayasaka, 1957). As noted by Chinzei (1978, p. 162), the Kurosawa fauna contains a mixture of nearshore (Shiobara-type) and offshore (Yama-type) molluscan assemblages. The Shiobara-type and Yama-type faunas are named for characteristic Miocene molluscan faunas that occur near Shiobara and Yama townsites in central and northern Honshu, respectively (Chinzei, 1978). The Tachilni fauna is somewhat closer in inferred paleoenvironment to the Shiobara-type assemblage, because of its preponderance of shallow water taxa. However, because of the high latitudes at which they occur, the Tachilni deposits expectably lack some characteristic Shiobara-type genera such as *Dosinia* Scopoli, 1777 and *Anadara* Gray, 1847, which are replaced by cooler water taxa such as *Mya* Linnaeus, 1758, *Clinocardium* Keen, 1936 and others.

The Tachilni fauna may correlate with the cold, shallow-water faunas of the Togeshita Formation, western Hokkaido (Marincovich, 1981b), and the Okkopezawa Formation, eastern Hokkaido. The Togeshita fauna is approximately of late Miocene age and consists of nearshore species preserved in coarse sandy matrix (Uozumi, 1962; Chinzei, 1978). The Okkopezawa fauna is of latest middle or late Miocene age (K. Ogasawara, oral commun., 1981). According to H. Noda (oral commun., 1981) the Okkopezawa molluscan fauna has often been cited by authors as the "Atsunai fauna" in the mistaken belief that it comes from the stratigraphically higher Atsunai Formation. The Tachilni fauna is not known to have species in common with the Togeshita fauna or the better-known Okkopezawa fauna. However, according to the unpublished data of K. Ogasawara (Tohoku University, Sendai, Japan), the Okkopezawa fauna contains the following genera that also occur in the Tachilni fauna: *Cyclocardia* Conrad, 1867, *Felaniella* Dall, 1899, *Glycymeris* Da Costa, 1778, *Macoma* Leach *in* Ross, 1819, *Mizuhopecten* Masuda, 1963, *Panomya* Gray, 1857, *Spisula* Gray, 1837, *Yoldia* Moeller, 1842, and *Natica* (*Tectonatica*) Sacco, 1890. The similarity in paleoenvironments implied by the shared genera of these formations, and their similar inferred ages, suggests further study to determine if they have any species in common.

PALEOECOLOGY

Tachilni mollusks are inferred to have lived in a cool-temperate inner shelf habitat (Allison, 1978; Marincovich, 1981b). My use of the term "cool-temperate" is in the sense of Hall (1964), who states that there are fewer than four months per year when shallow-water temperatures are warmer than 10°C (50°F) at the northern limit of this marine climatic zone. In the northeastern Pacific, the cool-temperate zone includes latitudes 48°N to 56°N (Puget Sound to the Gulf of Alaska), and in the northwestern Pacific it ranges from latitudes 41°N to 43°N (northernmost Honshu and eastern Hokkaido) (Hall, 1964). The modern representatives of Tachilni species useful for paleoclimatic inferences are listed in Text-figure 6, where their geographic ranges in the northeastern Pacific are depicted. The presence of these species clearly suggests a cool-temperate marine climate during Tachilni deposition. Species in Text-figure 6 with entirely cold-water modern habitats, such as *Periploma* (*Periploma*) *aleutica* (Krause, 1885) and *Siliqua alta* (Broderip and Sowerby, 1829), reinforce the inference of a cool-water habitat for the Tachilni fauna. This inference is supported by the presence in the Tachilni of the extinct taxa *Neptunea* (*Neptunea*) *lyrata altispira* Gabb, 1869 and *Neptunea* (*Golikovia*) *plafkeri* Kanno, 1971, whose earliest appearance in Alaska is in mid-Miocene glaciomarine deposits of the Yakataga Formation in the northeastern Gulf of Alaska (Kanno, 1971; Nelson, 1974). Additional cool-water indicators are *Natica* (*Tectonatica*) *janthostoma* Deshayes, 1839, which now lives mainly in the cool-temperate to cold waters from Hokkaido to Kamchatka, and the northern genus *Beringius* Dall, 1886, which in the northeastern Pacific ranges from British Columbia, Canada, to the Arctic Ocean (Dall, 1921, p. 90). Cool-water taxa occur throughout the formation and there is no evidence of marine climatic changes during Tachilni deposition.

The only southern extralimital species in the Tachilni fauna are *Polinices* (*Euspira*) *diabloensis* (Clark, 1915), known previously only from upper Miocene strata of northern and central California, and *Crenomytilus coalingensis* (Arnold, 1909), from upper Mio-



Text-figure 6.—Modern latitudinal ranges of northeastern Pacific mollusks in the Tachilni fauna. Provincial boundaries from Hall (1964). Dashed lines indicate uncertain or sporadic occurrences.

cene to Pleistocene faunas of central and southern California. Considering the convincing evidence for a cool-temperate Tachilni fauna, the presence of so few southern extralimital species is not surprising.

Twenty-one Tachilni genera and species, or their closely related modern analogues, are useful for paleobathymetric inferences (Text-fig. 7). Based on their modern depth records, the narrowest range of depths needed to account for the presence of these 21 taxa at a given site is the interval from 20 to 40 m depth. However, because not all taxa are present at each collecting locality, depths from the low tide line to 50 m are more realistic inferences for individual Tachilni localities. There is no evidence for change in water depth during deposition of the formation.

Carbonized plant debris, assumed to be of terrestrial origin, occurs throughout the Tachilni section. It is present to some degree at every outcrop, and is locally abundant. The abundance of plant material implies that a shoreline, and possibly a coastal river or stream, was near the Tachilni depositional site. A shallow-water regime is also implied at some outcrops by measurements of trough crossbeds resulting from bimodal current flow on a tidally-influenced inner-shelf bottom (H. McLean, written commun., 1982).

More than three-quarters of the Tachilni bivalve taxa (28 of 36 species-level taxa) were represented by at least one intact individual [having closed, articulated valves (Table 2)]. Many taxa are represented mostly or entirely by articulated, closed individuals, such as *Glycymeris grewingki* Dall, 1909, *Macoma* (*Macoma*) *optiva* (Yokoyama, 1923), *Lyonsia mooreae* n. sp., *Mya* (*Arenomya*) *elegans* (Eichwald, 1871), *Mya* (*Mya*) *truncata* Linnaeus, 1758, *Periploma* (*Periploma*) cf. *P.* (*P.*) *aleutica* (Krause, 1885), and *Peronidia* aff. *P. lutea alternidentata* (Broderip and Sowerby, 1829). In addition, specimens of *Lyonsia mooreae* and *Mya* (*Mya*) *truncata* were observed in living positions at outcrops, and a group of four specimens of the former species in apparent living positions has been preserved intact. This evidence from the bivalves strongly suggests that the Tachilni mollusk fauna was preserved entirely or largely *in situ,* and that faunal composition was not significantly affected by post-mortem transport by currents or wave action.

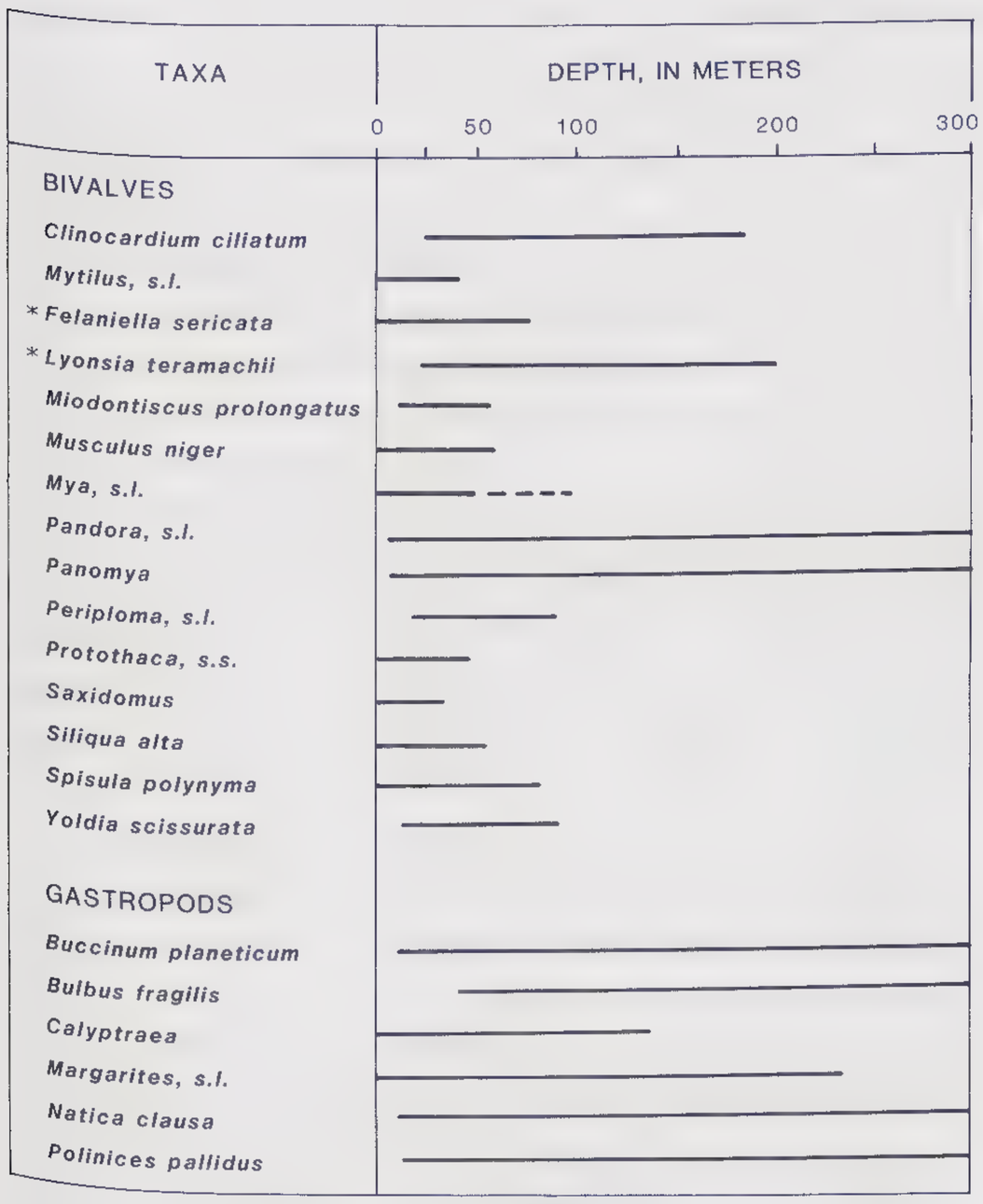
SYSTEMATIC PALEONTOLOGY

INTRODUCTION

The taxonomy and systematics used in this study are purposely conservative. This has been done because knowledge of Alaskan Tertiary molluscan faunas, and attempts at correlation around the North Pacific margin, are in their infancy. Innovative taxonomy would likely impair our developing understanding of broad scale biogeographic trends and obscure possible faunal correlations within this extensive region. Identification of Alaskan Tertiary mollusks involves bringing together three disparate literatures: the American, the Japanese, and the Russian. Any attempt to unify these philosophically divergent literatures requires caution, especially when dealing with species-level taxa. The lack of comparative collections in America from Japanese and Russian faunas is a major hindrance to making the detailed morphologic comparisons that are essential for identifying synonyms and understanding the true stratigraphic and geographic ranges of taxa. My greater familiarity with the American literature may have biased me in favor of using American taxonomy for species for which the use of Japanese or Russian names will later prove to be more useful. However, I think that the conservative philosophy employed here will make it easier in later studies to deal with, and possibly to modify, the species-level taxonomy for Tachilni mollusks. A basic assumption I make is that Alaskan Tertiary molluscan faunas contain greater numbers of species from Asia and from the mid-latitude northeastern Pacific (especially Oregon and Washington) than have been recognized previously. Future descriptive studies such as the present one will demonstrate the degree to which this is true.

Large collections of fossils inevitably contain many specimens too poorly preserved for confident identification to the species- or genus-level. Several of these indeterminate taxa in the Tachilni fauna are listed in Table 1. However, they are not specifically mentioned in the text, because they appear only to be imperfect remains of Tachilni species already discussed, not the remains of species new to this fauna.

The species synonymies given here are relatively short, and mostly contain only references providing original descriptions, significant discussions, or illustrations of each species. In the species synonymies and in Table 1 my usage of "cf.," "aff." and "?" refers in all cases to species-level taxonomy, not to generic allocations.



Text-figure 7.—Modern bathymetric ranges in the northeastern Pacific of some Tachilni mollusks or their living analogues. Asterisks indicate analogous species.

INSTITUTIONAL ABBREVIATIONS

ANSP—Academy of Natural Sciences, Philadelphia, Pennsylvania
BM(NH)—British Museum (Natural History), London, England
CAS—California Academy of Sciences, San Francisco, California
GS—Institute of Geology and Paleontology, Faculty of Science, Tohoku University, Sendai, Japan
GT—Geological Institute, Faculty of Science, Tokyo University, Tokyo, Japan
LSL—Linnaean Society of London, London, England
SMF—Senckenberg Museum, Frankfurt am Main, West Germany
SU—Stanford University, Stanford, California
SUPTC—Stanford University Paleontological Type Collection [now housed at CAS, see above]
TUE—Tokyo University of Education, Institute of Geology and Mineralogy, Tokyo, Japan
UA—University of Alaska, Fairbanks, Alaska
UCMP—University of California at Berkeley, Museum of Paleontology, Berkeley, California
USFC—U.S. Fisheries Commission, Washington, D.C.
USGS—U.S. Geological Survey, Menlo Park, California

USNM—National Museum of Natural History, Smithsonian Institution, Washington, D.C.
UZM—University Zoological Museum, Copenhagen, Denmark
ZIL—Zoological Institute, Leningrad, U.S.S.R.
ZMH—Zoologisches Museum, Humboldt Universitaet, Berlin, Germany

FORMAT

Taxonomic categories above the species level generally are not discussed here, except in the few cases where subgeneric assignments require comment. Because Alaskan Tertiary mollusks are so poorly known, the discussion for each Tachilni species notes the main morphologic characters and includes comparisons, some extensive, with similar species. Where measurements of mollusks are given they follow the standard usage of Cox (1960) for gastropods and Cox (1969) for bivalves. Extensive literature citations of the stratigraphic and geographic ranges of species are given in order to relate the Tachilni fauna as fully as possible to other North Pacific faunas.

Phylum **MOLLUSCA**

Class **BIVALVIA** Linnaeus, 1758

Family **NUCULIDAE** Gray, 1824

Genus **ACILA** H. and A. Adams, 1858

Subgenus **TRUNCACILA** Schenck *in* Grant and Gale, 1931

Acila (Truncacila) empirensis Howe, 1922
Plate 12, figures 1–4

Acila empirensis Howe, 1922, p. 96, pl. 9, figs. 4, 5, 8; Addicott, 1976a, p. 111, pl. 5, fig. 6.
Acila (*Truncacila*) *empirensis* Howe. Schenck, 1936, p. 85–86, pl. 9, figs. 3, 4, 6–10, 12; Weaver, 1942, pt. 1, p. 30–31, pl. 6, figs. 6, 7, 16; Addicott, Winkler, and Plafker, 1978, map sheet 2 [as "cf."].

Discussion.—This species is among the largest of the species of *Truncacila,* as shown by the two largest Tachilni specimens at 27.7 mm and 26.3 mm long, and 22.0 mm and 22.1 mm high, respectively. Schenck (1936, p. 86) listed his largest examined specimen at 25.9 mm long and 19.2 mm high. *Acila* (*Truncacila*) *empirensis* is also distinguished by its relatively high degree of inflation and its fine and weakly impressed radial sculpture. In common with closely related species of *Truncacila,* it has a band of obsolete radial ribbing along its ventral margin. The axis of bifurcation of the radial ribs is more inclined than in many other species of *Truncacila,* and secondary bifurcation of the ribs develops at an early stage. As noted by Schenck (1936, p. 86), this species is most similar to *A.* (*T.*) *conradi* (Meek, 1864), from which it was said to differ by having a ventral area of obsolete radial ribbing, larger size, and greater degree of inflation. The presence of obsolete radial ribbing along the ventral margin does not help to separate *A.* (*T.*) *empirensis* from *A.* (*T.*) *conradi,* however, because some of Schenck's (1936) illustrations of *A.* (*T.*) *conradi* (*e.g.,* pl. 8, figs. 12 and 14) clearly show obsolete radial ribbing along the ventral margins of some specimens. *Acila* (*Truncacila*) *empirensis* does seem to be larger than *A.* (*T.*) *conradi,* as Schenck (1936, p. 83) gives a maximum size of 21.7 mm long and 16.5 mm high for the latter species. The degree of inflation of the valves is similar for the two species, based on Schenck's (1936) illustrations and specimens on hand. The radial sculpture of *A.* (*T.*) *conradi* is relatively coarser than in *A.* (*T.*) *empirensis* and stands in bolder relief. The posterior termination of *A.* (*T.*) *empirensis* is distinctly angulate, whereas it is rounded in *A.* (*T.*) *conradi*; the escutcheon of the former species is clearly pouted or centrally raised, but is much reduced or lacking in *A.* (*T.*) *conradi.* The first report of *A.* (*T.*) *empirensis* in Alaska was by Schenck (1936, p. 85), who questionably identified it in the Yakataga district of the northeastern Gulf of Alaska, in rocks now assigned to the Yakataga Formation of Miocene to Pleistocene age. MacNeil *in* Miller (1957) noted that "some specimens resemble *A. empirensis* Howe" in collections presumably from the Yakataga Formation. Addicott, Winkler, and Plafker (1978) also listed *Acila* (*Truncacila*) cf. *A.* (*T.*) *empirensis* from presumed Wishkahan faunas of the Yakataga Formation in the northeastern Gulf of Alaska. Thus, specimens from the Tachilni Formation are only the fourth reported occurrence, and the first verified report, of this species in Alaska. In Oregon and Washington, *A.* (*T.*) *empirensis* has its highest stratigraphic occurrence in the Moclipsian Stage (Addicott, 1976a, p. 111). The species has not subsequently been found in Newportian faunas, so its known stratigraphic range is Wishkahan through Moclipsian and helps to establish a lower age limit for the Tachilni fauna.

Type information.—Holotype: UCMP 30032. Type locality: Coos Bay, southwestern Oregon; Coos Conglomerate Member of the Empire Formation; upper Miocene.

Tachilni Formation occurrence.—USGS localities M309 (1 valve, as "cf."), M7146 (1 valve, as "cf."), M7150 (1 articulated, closed specimen, as "cf."); UA locality A-169 (abundant valves); CAS locality 60278 (3 articulated, closed specimens).

Figured specimens.—UA 2467, 2468.

Stratigraphic and geographic range.—Known only

in Miocene and Pliocene faunas of Alaska and the Pacific Northwest. Lower upper Miocene (Wishkahan): Coos Conglomerate Member of Empire Formation, southwestern Oregon (Howe, 1922); Quillayute Formation, western Olympic Peninsula, northwestern Washington (Weaver, 1942). Upper Miocene: Montesano Formation at Taholah, Aberdeen, and 1.5 mi north of Cape Elizabeth, western Washington (Schenck, 1936). Upper (?) Miocene: Yakataga Formation, Yakataga district (Schenck, 1936, as "questionably identified"; MacNeil *in* Miller, 1957, as a possible identification), Malaspina district (MacNeil *in* Miller, 1957, as a possible identification), and Lituya district (Addicott, Winkler, and Plafker, 1978, as "cf.").

Acila (Truncacila) ermani (Girard, 1843)
Plate 12, figures 5–7

Nucula ermani Girard, 1843, p. 545–546, figs. 8a, b; Grewingk, 1850, p. 154, 280–281, pl. 5, figs. 1a, b [not figs. 4a, b, as stated].
Nucula (*Acila*) *ermani* Girard. Dall, 1896, p. 844; Dall, 1898, p. 572–573; Dall, 1899, p. 546; Grant and Gale, 1931, p. 117 [as "*ermanni*"].
Acila (*Truncacila*) *ermani* (Girard). Schenck, 1935, p. 1, 2; Schenck, 1936, p. 95–96, text-fig. 7(11).

Discussion.—This species is unique among Tertiary species of *Truncacila* in having radial sculpture so fine and weakly impressed that it is nearly invisible. Other distinguishing characters are its large size (the largest Tachilni valve is 35.8 mm long and 28.0 mm high) and broadly rounded anterior and posterior extremities. The Tachilni specimens have a band of obsolete radial ribbing that is 5 mm wide at the midpoint of the ventral margin, though this feature is not shown in the drawing of the type specimen (Girard, 1843; Grewingk, 1850). *Acila* (*Truncacila*) *ermani* is among the rarest of Alaskan Tertiary mollusks. The only previously published illustration of it is the drawing of the type specimen in Girard (1843), which was reproduced by Grewingk (1850). Schenck (1936) provided only an outline drawing of the shell, derived from the figures of Grewingk (1850), and apparently lacked specimens to examine. The principal morphologic features noted above clearly distinguish this species from others of *Truncacila*. The best-preserved Tachilni specimen is a left valve that is missing its anterior dorsal margin and the exterior surface on its early portion. Except for a ventral band of obsolete sculpture, all of the preserved shell surface is covered with extremely weak radial costellae. The radial sculpture is weakest across the central portion of the valve and strongest along the posterior dorsal margin. Very fine concentric growth lines and somewhat coarser corrugations are well preserved and demonstrate that the weak radial sculpture is original and not produced by abrasion or weathering. The interior ventral margin is smooth except for very fine, short crenulations at its anterior end. Girard (1843) described *A.* (*T.*) *ermani* from a single place, Atka Island in the Aleutian Islands (Text-fig. 1), but did not cite a precise locality. Grewingk (1850, p. 154) noted an occurrence of the species in sandstone at "Sand Bay" ("Sandbucht"), which he placed along the north side of Korovin Bay, an embayment on the north-west side of Atka Island. An unnamed, shallow, sandy-bottomed lagoon is present on the north side of Korovin Bay, and a USGS field party explored this area in 1979 to locate the strata bearing *A.* (*T.*) *ermani*. Despite Girard's (1843, p. 546) description of the fossil-bearing stratum as a "coarse volcanic tuff," and Grewingk's (1850, p. 154) directions to a "30-foot-high bed of loose sandstone and hard claystone with fossils" at "Sand Bay," no fossils were found. There is a long-abandoned Russian townsite of Korovinski at the mouth of "Sand Bay," however, so nineteenth century fur sealers or explorers could have collected fossils from this area.

Additional Alaskan occurrences of *A.* (*T.*) *ermani* were reported in the Pribilof Islands, on St. Paul Island (Dall, 1896) and St. George Island (Dall, 1899). Although Schenck (1936) mentioned these localities he was unable to locate the specimens upon which Dall based his reports, and further stated that the whereabouts of the holotype was unknown. Besides the Tachilni shells, other specimens from the Alaska Peninsula are on hand from USGS localities M3588 and M5173. Both localities are in the Miocene Bear Lake Formation. The exact location of M3588 is unknown and M5173 is near Bear Lake (Text-fig. 2), but specimens from both collections are in identical matrix, so they may represent nearby sites. The larger collection, from M3588, contains about 25 specimens that show the weak radial sculpture that becomes obsolete ventrally, the large size, and the broadly rounded extremities of the Tachilni specimen. At USGS locality M3588 most specimens of *A.* (*T.*) *ermani* are articulated and closed and occur with the intertidal bivalve *Septifer* sp., which suggests that the nuculid lived in extremely shallow water there.

Type information.—Holotype: location unknown (Schenck, 1936). Type locality: "in a hard volcanic tuff," Atka Island, Aleutian Islands, Alaska (Girard, 1843); formation and age unknown.

Tachilni Formation occurrence.—USGS localities M309 (1 valve, as "cf."), M7140 (3 valves); CAS localities 60279 (1 articulated specimen), 60280 (1 valve).

Figured specimen.—USNM 265854.

Stratigraphic and geographic range.—Known only

in presumed Miocene strata of Alaska. Probable middle or upper Miocene: unnamed upper member of Bear Lake Formation, Alaska Peninsula (USGS coll.). Miocene (?): unnamed formation, Atka Island, Aleutian Islands (Girard, 1843; type loc.); unnamed formations on St. Paul and St. George Islands, Pribilof Islands (Dall, 1896, 1899).

Family **NUCULANIDAE** H. and A. Adams, 1858

Genus **YOLDIA** Moeller, 1842

Subgenus **CNESTERIUM** Dall, 1898

Yoldia (Cnesterium) scissurata Dall, 1897
Plate 12, figures 8, 9

Yoldia scissurata Dall, 1897, p. 8 [new name for *Yoldia arctica* Broderip and Sowerby, 1829, not Gray, 1824].
Cnesterium scissurata (Dall). Addicott, 1976a, p. 108, 113, pl. 4, fig. 3, pl. 5, fig. 26.

Discussion.—This species is characterized by a large shell with a broadly rounded but slightly produced anterior end, and a strongly attenuated and upturned posterior end. The beaks are closer to the posterior end and the anterior dorsal margin is elevated and smoothly rounded. A low, bladelike projection along the posterior dorsal margin is partially preserved in one specimen (Pl. 12, fig. 9). The oblique concentric sculpture is developed best on the posterior portion of the shell and obsolete or absent on the anterior portion.

Tachilni individuals are larger than those noted in modern populations. The three most complete Tachilni specimens have lengths of 52.4, 45.3 and 43.4 mm, whereas a "maximum length to 40 mm" was noted for modern specimens from the western Beaufort Sea (Bernard, 1979a, p. 21).

This species is similar in outline and sculpture to several other North Pacific species of *Cnesterium,* notably *Y.* (*C.*) *ensifera* Dall, 1897, *Y.* (*C.*) *seminuda* Dall, 1871; *Y.* (*C.*) *strigata* Dall, 1909, and *Y.* (*C.*) *kuluntunensis* Slodkewitsch, 1936. Some workers have considered *Y.* (*C.*) *scissurata* and *Y.* (*C.*) *ensifera* to be synonymous (Grant and Gale, 1931, p. 131; Kanno, 1971, p. 39; Bernard, 1979a, p. 21), but MacGinitie (1959, p. 154–155) and Roth (1979, p. 214) cited conchological characters for separating the two. MacGinitie (1959) noted that *Y.* (*C.*) *scissurata* is higher anteriorly and has a relatively longer anterior end and shorter posterior end (measured from the umbo) than *Y.* (*C.*) *ensifera*. She also observed that the posterior dorsal blades are longer and higher and the posterior rostrum more upturned in *Y.* (*C.*) *ensifera*. Roth (1979) further noted that *Y.* (*C.*) *ensifera* is equilateral and strongly compressed, whereas *Y.* (*C.*) *scissurata* is more inflated and has its beaks posterior to the midline, and that the oblique, grooved sculpture of the latter species tends to be coarser. Based on Holocene collections at the California Academy of Sciences, Roth (1979) gave the range of *Y.* (*C.*) *scissurata* as Point Barrow to Kodiak Island, Alaska, and the range of *Y.* (*C.*) *ensifera* as British Columbia to southern California, with an intervening gap of about 1,500 km (900 mi).

Yoldia (*Cnesterium*) *strigata* Dall, 1909, described from the Wishkahan Empire Formation at Coos Bay, Oregon, has been considered a subspecies of *Y.* (*C.*) *scissurata* by some workers (Grant and Gale, 1931, p. 131; Weaver, 1942, p. 51) and a junior synonym of it by others (Bernard, 1979a, p. 21). The oblique concentric sculpture that is obsolete or absent from the anterior portions of Tachilni individuals and USGS Bering Sea Holocene specimens here assigned to *Y.* (*C.*) *scissurata,* is evidently well developed on the anterior of *Y.* (*C.*) *strigata* (Dall, 1909; Weaver, 1942; Roth, 1979). Anterior oblique concentric sculpture is well developed on Beaufort Sea specimens assigned to *Y.* (*C.*) *scissurata* by Bernard (1979a), so criteria for recognizing species in this species-complex evidently are not well-defined. As a further complication, *Y.* (*C.*) *seminuda,* known in Pliocene(?) or Pleistocene to Holocene faunas of the northeastern Pacific (Dall, 1871; Roth, 1979), is characterized by an anterior end that commonly lacks concentric sculpture, and is otherwise very similar in outline to *Y.* (*C.*) *scissurata*. A taxonomic review of this species-complex may result in *Y.* (*C.*) *seminuda* being recognized as the earliest proposed name for a highly variable species.

The most closely related Asian Tertiary species appears to be *Y.* (*C.*) *kuluntunensis* Slodkewitsch, 1936, reported in middle to upper Miocene strata of the Kakert, Etolon, Erman(?) and coeval formations of West Kamchatka, Sakhalin, and Karaginsky Island (Slodkewitsch, 1936, 1938a, 1938b; Gladenkov, 1972, 1977). Published illustrations of *Y.* (*C.*) *kuluntunensis* do not allow detailed comparisons with *Y.* (*C.*) *scissurata,* but the former species appears to differ from the latter mainly by having well-developed oblique concentric sculpture over its entire shell surface. Most related Asian Tertiary species of *Cnesterium* are treated in works by Khomenko (1931, 1937), Uozumi (1957), and Gladenkov (1972). Roth (1979, p. 213) gave a modern depth range of 13 to 92 m for *Y.* (*C.*) *scissurata*.

Type information.—Holotype: presumably in BM(NH). Type locality: unknown.

Tachilni Formation occurrence.—USGS localities M7144 (1 valve), M7146 (abundant valves), M7150 (abundant articulated specimens), M7256 (2 valves); UA locality A-301 (1 articulated specimen, 1 valve).

Figured specimens.—USNM 265855; UA 2469.

Stratigraphic and geographic range.—Because of widespread confusion between *Y.* (*C.*) *scissurata* and similar species, published occurrences of this species are impossible to evaluate. A modern northern range limit at about Point Barrow, northwestern Alaska, is generally agreed upon, but cited southern limits vary from Kodiak Island, Alaska (Roth, 1979), to the Gulf of California, Mexico (Parker, 1964, p. 157). The earliest geologic occurrence is equally uncertain. Addicott (1976a, p. 110) stated that *Y.* (*C.*) *scissurata* first appeared in the Pacific Northwest in Graysian faunas.

Family **GLYCYMERIDIDAE** Newton, 1922

Genus **GLYCYMERIS** Da Costa, 1778

Glycymeris grewingki Dall, 1909
Plate 12, figures 10–17

?*Pectunculus kaschewarowi* Grewingk, 1850, p. 51, 94, 98, 190, 279–280, pl. 5, figs. 3a–3d [*nomen dubium*].
Glycymeris grewingki Dall, 1909, p. 107, pl. 2, fig. 13.
Glycymeris gabbi Dall, 1909, p. 108, pl. 11, fig. 5.
?*Glycymeris conradi* Dall, 1909, p. 107–108, pl. 11, fig. 2 [not *Axinaea conradi* Whitfield, 1885; renamed *Glycymeris larvata* Hanna, 1924].
?*Glycymeris coalingensis* Arnold, 1909, p. 80–82, pl. 19, fig. 3.

Discussion.—This is a characteristic Tachilni bivalve that occurs abundantly at some outcrops. The valves are commonly about 40 mm long, may be equidimensional, but are usually slightly longer than high. The lower two-thirds of the valve margin forms a smooth, nearly circular curve. The umbo is prominent and placed very slightly to distinctly nearer to the posterior extremity. The principal radial sculpture consists of 30 to 35 low, rounded costae separated by much narrower interspaces. The radial costae of most, but not all, specimens gradually become obsolete toward the posterior extremity, and some specimens also have obsolete radial ribbing along the ventral margin. Radial costae are absent along the dorsal margins. Extremely fine, closely-spaced radial costellae are present across the whole exterior of each valve and become obsolete only along the dorsal margins. Concentric sculpture consists only of incremental growth lines which, when very fine, form a minute reticulate pattern where they intersect the radial costellae.

The earliest name for this species may be *G. kaschewarowi* (Grewingk, 1850), but the original description given by Grewingk does not closely match his four illustrations, so the identity of his species remains a question. *Glycymeris kaschewarowi* was described as having 50 radial costae, but Grewingk's illustrations (1850, pl. 5, figs. 3a, d) show two valves with countable radial ribs and these have 29 and 24 ribs, respectively. In addition, he states that each valve has 28 hinge teeth, but shows 29 teeth on one valve (fig. 3c) and 31 teeth on another (fig. 3b). Tachilni specimens of *Glycymeris* are not preserved well enough for complete tooth-counts. Grewingk's stated measurements of length 47 mm, height 45 mm are similar to those of the largest Tachilni specimens. The circular outline and elevated umbo of *G. kaschewarowi* are similar to those of several North Pacific species of *Glycymeris*. Grewingk (1850) cited *G. kaschewarowi* occurring on the Alaska Peninsula at Pavlof Volcano and Pavlof Settlement (now abandoned), both on the west side of Pavlof Bay (Text-fig. 2) and about 80 km northeast of Cape Tachilni, as well as on St. Paul Island in the Pribilof Islands, Bering Sea, and on Unga and Kodiak Islands, western Gulf of Alaska (Text-figs. 1, 2). It is likely that Grewingk's type specimens are lost, because Kafanov (1980, p. 305) states that the holotype of an Alaskan Tertiary species of *Cardium* described by Grewingk (1850) and presumed to be in Leningrad is lost. In view of Grewingk's (1850) confusing original citation of *G. kaschewarowi,* and the availability of other names for Tachilni specimens of *Glycymeris,* his species name is considered here to be a *nomen dubium.*

Glycymeris grewingki and *G. gabbi* Dall, 1909, were described in the same publication and first synonymized by Arnold and Hannibal (1913) under the former name, though not all later workers have maintained that usage. A third species of *Glycymeris* named by Dall (1909) in the same publication, *G. conradi,* is also probably a synonym of *G. grewingki.* All three of Dall's (1909) species have their type localities in the Empire Formation at Coos Bay, Oregon. Recent collections made from these beds suggest the presence of only one species of *Glycymeris* in the Empire Formation (Roth, oral commun., 1979).

Glycymeris coalingensis Arnold, 1909, of central and southern California, has been considered a synonym of *G. grewingki* by several workers (Howe, 1922; Grant and Gale, 1931; Woodring, Stewart, and Richards, 1940; Hertlein and Grant, 1972). If this is accepted then *G. grewingki* is not restricted to faunas of Wishkahan age as stated by Addicott (1976a, as "*G. gabbi*") for Pacific Northwest faunas, but ranges into both older and younger rocks, as noted by Roth (1979, p. 236).

The Asiatic species most similar to *G. grewingki* is *G. yessoensis* (Sowerby, 1889), a taxon reported in Neogene strata from northern Honshu and Hokkaido to Sakhalin and western Kamchatka. The two species are similar in shape and sculpture, though *G. yessoensis* may have a greater average size; 42 specimens

of *G. yessoensis* from the Pliocene Omma Formation measured by Ogasawara (1977, p. 94) showed some individuals reaching about 50 mm in length and height, which is larger than any Tachilni specimen. Ogasawara's (1977) study also demonstrated that his specimens had a consistently greater length than height throughout ontogeny; in contrast most specimens of *G. grewingki* are virtually equidimensional. Based on published illustrations of *G. grewingki* and *G. yessoensis*, these species may be separable by the number of crenulations along the interior ventral shell margin. It appears that *G. grewingki* has about 20 to 22 crenulations and *G. yessoensis* about 26 to 29. Tachilni specimens of *G. grewingki* have 20 to 21 crenulations.

Illustrations of "*G. coalingensis*" given by Slodkewitsch (1938b, p. 104, pl. 9, figs. 4, 5, 5a) seem identical to the Tachilni species. Slodkewitsch (1938a, 1938b) cites this species as "uncommon" in the "lower horizon of the Kavran" Group in western Kamchatka, strata now referred to the Kakert Formation of the Kavran Group and assigned a middle Miocene age (Menner, Baranova, and Zhidkova, 1977; Gladenkov, 1980). The same author reports *G. yessoensis* in strata now assigned to the overlying Etolon Formation of the Kavran Group in western Kamchatka (Slodkewitsch, 1938b, p. 104), but not in older rocks.

Glycymeris grewingki occurs throughout Tachilni strata and is locally abundant. About half of all specimens are articulated and have their valves closed or slightly agape. The genus is common in the North Pacific today and is reported from the intertidal zone to 365 m depth in the northeastern Pacific (Keen and Coan, 1974).

Type information.—Holotype: USNM 107784. Type locality: Coos Bay, southwestern Oregon; Empire Formation; upper Miocene.

Tachilni Formation occurrence.—USGS localities M309 (2 valves), M5163 (13 articulated, closed specimens, 6 valves), M7139 (1 articulated, closed specimen, 1 valve), M7142 (2 articulated, closed specimens, 1 valve), M7146 (2 articulated, closed specimens, 5 valves), M7201 (2 articulated specimens, 1 valve); UA locality A-170 (2 articulated, closed specimens, 4 fragments); CAS locality 60280 (3 valves).

Figured specimens.—USNM 339752, 339753; UA 2470, 2471, 2472.

Stratigraphic and geographic range.—The occurrence of this species is uncertain, due to questions of synonymy with other species. The species is considered to be restricted in the Pacific Northwest to Wishkahan strata (Addicott, 1976a), including the Empire Formation at Coos Bay (Dall, 1909; Howe, 1922), and at Cape Blanco (Roth, 1979, p. 236), Oregon, and the Skonun Formation, British Columbia, Canada (Addicott, 1978). If *G. coalingensis* is a synonym, then occurrences include the middle Miocene Oursan Formation near Pleasanton, Alameda County, northern California (Hall, 1958), the Jacalitos Formation (of former usage) and the lower part of the Etchegoin Formation of central California (Woodring, Stewart, and Richards, 1940; Adegoke, 1969; Stanton and Dodd, 1976), and the Pliocene San Diego Formation near San Diego, southern California (Hertlein and Grant, 1972).

Family **MYTILIDAE** Rafinesque, 1815

Genus **CRENOMYTILUS** Soot-Ryen, 1955

Crenomytilus coalingensis (Arnold, 1909)

Plate 13, figure 1

Mytilus (*Mytiloconcha*) *coalingensis* Arnold, 1909, p. 73–75, pl. 19, fig. 5, pl. 22, fig. 6; Arnold and Anderson, 1910, p. 108, 125, pl. 41, fig. 5, pl. 44, fig. 6; Grant and Gale, 1931, p. 246.

Mytilus coalingensis Arnold. Woodring, Stewart, and Richards, 1940, p. 90, pl. 32, figs. 3, 4.

Crenomytilus coalingensis (Arnold). Soot-Ryen, 1955, p. 23.

Mytilus (*Crenomytilus*) *coalingensis sternbergi* Hertlein and Grant, 1972, p. 163–164, pl. 41, figs. 10, 14.

Discussion.—This robust mytilid is characterized by its large size, straight to slightly concave ventral margin, shell that is greatly thickened in the apical region, moderately coarse concentric sculpture, and fine, faint radial striae. It is the largest known Alaskan Tertiary mytilid.

Apexes of the Tachilni specimens are not well preserved, so it is not known if they are "elongate falcate and longitudinally grooved and ridged" as Arnold (1909, p. 73) noted for the type specimens from the Kettleman Hills of southern California. Proportions of the existing Tachilni shells do suggest, however, that the apexes were elongate. In all other details of morphology as well as size Tachilni specimens are identical to Kettleman Hills specimens of *C. coalingensis* figured by Arnold (1909) and Woodring, Stewart, and Richards (1940).

Variation in shell outline of *C. coalingensis* is well illustrated by two specimens described by Woodring, Stewart, and Richards (1940, pl. 32, figs. 3, 4) from one locality in the type area. The two adult shells differ strongly in length, as well as in sinuosity of the ventral margins, inflation of the dorsal margin, falcation of the apexes, inflation of the valves, and coarseness of the concentric growth lines. These differences are greater than among any of the Tachilni specimens. *Crenomytilus coalingensis sternbergi* Hertlein and Grant, 1972, described from the Pliocene San Diego Formation of southern California, was said to differ from typical *C. coalingensis* by having valves that are less

convex. This variant is present in populations of *C. coalingensis* from the Kettleman Hills, however, so the distinctive character of the San Diego subspecies is lost.

The fine crenulations of the interior margin, especially the anterior ventral margin, that characterize *Crenomytilus* (Soot-Ryen, 1955, p. 23) are not visible on Tachilni specimens, of which no interiors are well-preserved. The extremely fine and closely spaced radial striae of *C. coalingensis* are clearly present on better-preserved portions of the worn Tachilni shells.

At least ten Miocene mytilids have been described from California (Keen and Bentson, 1944, p. 71–72). Some of these are probably synonymous with *C. coalingensis,* especially considering the broad morphologic range of that species. Among the likely synonymous species are *Mytilus perrini* Clark, 1915, and *M. trampasensis* Clark, 1915, from upper Miocene strata of the San Pablo Group in northern California, and possibly *M. kewi* Nomland, 1916, from the upper Miocene Etchegoin Formation of the Kettleman Hills, southern California. *Crenomytilus coalingensis* has not been reported from the Pacific Northwest, where its closest relative is *Mytilus ficus* Dall, 1909, described from the Wishkahan Empire Formation at Coos Bay, southwestern Oregon. Krishtofovich (1964, p. 189, pl. 45, fig. 3, pl. 46, figs. 1, 1a) cites "*Mytilus* (*Mytiloconcha*) aff. *coalingensis*" from Miocene strata on Sakhalin, but her illustrated specimens are too worn for identification. Gladenkov (1977) noted *C. coalingensis* restricted to the Erman "horizon" of the easternmost U.S.S.R. The Russian mytilid most similar to *C. coalingensis* appears to be *Mytilus kamtschaticus* Slodkewitsch, 1938a (p. 114–115, pl. 46, figs. 4, 4a, pl. 47, fig. 1), reported from the Miocene Kavran Group along the Vayampol River of western Kamchatka and in the vicinity of Popupianya Bay, eastern Kamchatka. The Russian species evidently differs most from *C. coalingensis* by lacking radial sculpture, though the two species resemble each other in gross morphology. Zhidkova (1972, p. 116, pl. 38, fig. 1, pl. 39, figs. 1–4) illustrated *Crenomytilus* cf. *C. grayanus* (Dunker, 1853) from the "Pliocene" Parushaya Formation of Iturup Island, Kuril Islands, and some of the poorly preserved illustrated specimens could represent *C. coalingensis*. There appear to be no Japanese records of *C. coalingensis*.

In the modern northeastern Pacific, species of *Mytilus* Linnaeus, 1758 live attached to hard substrates from the intertidal zone to 40 m depth (Keen and Coan, 1974). *Crenomytilus grayanus* (Dunker, 1853), the type species of *Crenomytilus,* is the only modern species assigned to *Crenomytilus* by Soot-Ryen (1955). It lives in northern Japanese waters, where it has been collected in depths from the intertidal zone to 168 m (Nomura and Hatai, 1936).

Type information.—Holotype: USNM 165551. Paratype: USNM 165557. Type locality: "At northwest of Anticline Ridge, 6 mi north-northeast of Coalinga, SW. ¼ sec. 34, T. 19 S., R. 15 E. Lowest Etchegoin bed or *Glycymeris* zone," Fresno County, southern California (Arnold, 1909, p. 33); Etchegoin Formation; upper Miocene.

Tachilni Formation occurrence.—USGS localities M4045 (4 articulated, closed specimens, 3 valves), M7142 (fragments of 3 specimens), M7200 (1 articulated, closed specimen); UA locality A-169 (2 articulated, closed specimens).

Figured specimen.—USNM 339754.

Stratigraphic and geographic range.—There are extensive records of this species in upper Miocene strata of central and southern California, with fewer reports in Pliocene or Pleistocene rocks. Upper Miocene: Etchegoin and San Joaquin Formations, Coalinga region, central California (Arnold, 1909; Arnold and Anderson, 1910; Woodring, Stewart, and Richards, 1940; Adegoke, 1969); Castaic Formation, Los Angeles County, southern California (Stanton, 1966); Pancho Rico Formation, Salinas Valley, central California (Durham and Addicott, 1965). Presumed upper Miocene of San Pablo Group, Contra Costa County, northern California (Clark, 1915). Upper Miocene or (?)lower Pliocene: Towsley Formation, Los Angeles County, southern California (Kern, 1973). (?)Pliocene: Niguel Formation, Orange County, southern California (Vedder, 1961). (?)Pliocene or Pleistocene: Fernando Formation, Orange County, southern California (Zinsmeister, 1970); Merced Formation, northern California (Martin, 1916); San Diego Formation of San Diego County, southern California, and northwestern Baja California, Mexico (Hertlein and Grant, 1972).

Genus **MUSCULUS** Roeding, 1798

Musculus (Musculus) niger (Gray, 1824)
Plate 13, figures 2, 3

Modiola nigra Gray, 1824, p. 244.

not *Modiolaria nigra* (Gray). Khomenko, 1931, p. 58–59, pl. 10, fig. 1 [=*M. kryshtofovitschi* Krishtofovich (*ex* Simonova MS), 1964]; Slodkewitsch, 1938b, pl. 54, figs. 10–12 [=*M. kryshtofovitschi*].

Modiolaria nigra (Gray). Slodkewitsch, 1938b, p. 119, pl. 54, fig. 9.

Musculus niger (Gray). MacGinitie, 195, p. 157–158, pl. 18, fig. 6, pl. 21, fig. 6.

Musculus nigra (Gray). Ilyina, 1963, p. 118, pl. 51, fig. 10.

Musculus (*Musculus*) *niger* (Gray). Bernard, 1979a, p. 27–28, fig. 37.

Discussion.—This is the first report of this distinctive species of *Musculus* in Tertiary rocks of Alaska.

Musculus niger is the largest member of the genus (Bernard, 1979a, p. 28) and is further characterized by its relatively elongate proportions, sculpture of numerous, fine radial threads on its posterior portion, a smooth central part of the valve, and fewer and more widely spaced anterior radial ribs. The strength of the anterior radial ribs evidently varies, because the anterior ribs of Tachilni specimens are much weaker than on modern Beaufort Sea specimens discussed by Bernard (1979a, p. 28), but similar in strength to those of modern Beaufort, Chukchi and Bering Sea specimens in USGS collections. Bernard (1979a, p. 27) cites a maximum shell length of 45 mm for Beaufort Sea Holocene specimens, but several Tachilni specimens exceed 60 mm in length, and one modern USGS specimen from Peard Bay, northwest Alaska is 71 mm long.

Dall (1921, p. 23–24) lists 11 species of *Musculus* that occur in Alaskan waters, but the true number of Alaskan species is smaller. Bernard (1979a, p. 27) lists three species and subspecies as synonyms of *M. niger*. The large size, elongate proportions, and fine, clearly expressed posterior radial sculpture of *M. niger* distinguish it from other species of *Musculus*. No other species of *Musculus* is reported in Alaskan Tertiary faunas.

Musculus niger has been reported in eastern Kamchatka, in unnamed Miocene (?) beds along the Great Chazhma River (Slodkewitsch, 1938b, p. 119), and in the upper Miocene (?) Konstantinovsk beds of the Valaginsk Range (Ilyina, 1963, p. 118). Khomenko (1931, p. 108) has also reported this species in the Miocene and Pliocene "Supranutovo Group" [=upper part of Nutovo Formation, *fide* Krishtofovich (1964)] along the Great Garomai River of eastern Sakhalin. Krishtofovich (1964, p. 196–197) subsequently named *Musculus kryshtofovitschi* Krishtofovich (*ex* Simonova MS),* 1964, and allocated to it Khomenko's (1931) and Slodkewitsch's (1938b) records of *M. niger* from Sakhalin and Kamchatka. Illustrated specimens of *M. kryshtofovitschi* clearly differ from *M. niger* by having a relatively higher shell, an obliquely truncated anterior end, and posterior radial threads of varied width. However, Ilyina's (1963) record of *M. niger* from the upper Miocene (?) Konstantinovsk beds of eastern Kamchatka appears to be valid, based on her illustrated specimen. Ilyina (1963, p. 118) notes that she had earlier described "*Modiolaria osipovskiensis* Ilyina," and implies that it is a junior synonym of *M. niger*, but she gives no further reference to the name.

Musculus niger is a circumboreal species that lives in the Pacific as far south as southern California and the Sea of Japan, and is found from the low intertidal zone to 60 m depth (Bernard, 1979a, p. 28). All Tachilni specimens are disarticulated, which may have been caused by this species frequently having its anterior end only buried in substrate, as seen in modern populations (Bernard, 1979a, p. 28).

Type information.—Holotype: in BM(NH), number unknown. Type locality: Orsund Bay, Sweden (Oldroyd, 1924).

Tachilni Formation occurrence.—USGS localities M310 (1 valve), M7146 (abundant valves), M7258 (1 articulated specimen, 2 valves).

Figured specimens.—USNM 339755, 339756.

Stratigraphic and geographic range.—This species is reported in upper Miocene to Holocene faunas. Upper Miocene (?): Konstantinovsk beds, Valaginsk Range, eastern Kamchatka (Ilyina, 1963). A report of this species in Miocene beds on Unga Island, western Gulf of Alaska (Dall, 1896, p. 844) is probably in error. There are numerous records from Pleistocene deposits of circumarctic regions, including the Gubik Formation of northern Alaska (USGS collections). This species is cited as a modern panarctic and circumboreal one by Bernard (1979a), living in the Pacific as far south as the Sea of Japan and Santa Barbara, southern California. Bernard (1979a, p. 28) gives northeastern Pacific occurrences from the low intertidal zone to 60 m depth, cites Beaufort Sea records of 27–64 m and notes that other workers have reported finds as deep as 376 m.

Family **PECTINIDAE** Rafinesque, 1815

Genus **CHLAMYS** Roeding, 1798

Subgenus **SWIFTOPECTEN** Hertlein, 1935

Chlamys (Swiftopecten) cosibensis cosibensis
(Yokoyama, 1911)
Plate 13, figures 4–9, Plate 14, figures 1, 2

Pecten cosibensis Yokoyama, 1911, p. 4, pl. 1, figs. 3, 4.
Pecten turpiculus Yokoyama, 1925, p. 18, pl. 2, fig. 4.
Pecten heteroglyptus Yokoyama, 1926, p. 304, pl. 33, figs. 1–5, 8.
Chlamys cosibensis (Yokoyama). Masuda, 1959, p. 122–125, pl. 13, figs. 1–9; Masuda, 1973, p. 110–113, pl. 8, figs. 1–15, pl. 9, figs. 1–14.
Chlamys cosibensis cosibensis (Yokoyama). Masuda, 1962, p. 162–163.
Chlamys (Swiftopecten) donmilleri MacNeil, 1967, p. 12, pl. 3, figs. 1, 4, 6.
Chlamys (Swiftopecten) leohertleini MacNeil, 1970, p. 70, figs. 1–3.

Discussion.—Tachilni specimens of *Chlamys (Swiftopecten) cosibensis cosibensis* display a char-

* Krishtofovich (1964, p. 196) attributed authorship of *Modiolaria kryshtofovitschi* to A. Simonova, who wrote an unpublished manuscript in 1939. Because Simonova's manuscript evidently was never published, authorship of the species belongs to Krishtofovich (1964), who was the first to name and describe the species in print.

acteristically broad range of sculptural variation. All specimens have well-developed radial and concentric sculpture, although the expression of these differs greatly between left and right valves. The primary radial costae of the left valve are much narrower than the interspaces, whereas the opposite is true of the right valve. Both valves have densely crowded secondary and tertiary radial costae of varying strength. Concentric sculpture of the left valve consists of broad folds sharply raised into nodes where they intersect primary radial costae. On the right valve, concentric sculpture is made up of broad steps or constrictions. The complexities of sculptural variation and the taxonomic history for this species have been detailed by Masuda (1959, 1962, 1972, 1973). Many Tachilni individuals are larger than the largest Japanese specimen noted by Masuda (1959, p. 124) as 74.2 mm high and 70.4 mm long. The largest Tachilni specimen, from USGS locality M7139, has slightly broken margins but still is 109 mm high and 93 mm long.

The first report of *C.* (*S.*) *cosibensis, s.l.,* in Alaska was by MacNeil (1967, p. 17), who tentatively recognized it on Tugidak Island, western Gulf of Alaska, in beds now assigned to the Tugidak Formation (Moore, 1969, p. A34), of late Pliocene and Pleistocene age (Allison, 1978, p. 177). Masuda (1973, p. 113) later stated that MacNeil's (1967) Tugidak specimens were definitely not *C.* (*S.*) *cosibensis, s.l.,* with which I agree, but he did not assign another name to them. MacNeil also named two other species of *Chlamys* from Alaskan faunas: *Chlamys* (*Swiftopecten*) *donmilleri* MacNeil, 1967, from presumed middle Miocene beds of the Yakataga Formation, Yakataga district, northeastern Gulf of Alaska, and *C.* (*S.*) *leohertleini* MacNeil, 1970, from the type locality of the Tachilni Formation. *Chlamys* (*Swiftopecten*) *donmilleri* also has been reported in the early and (or) middle Miocene (Allison, 1978, p. 174) Unga Conglomerate Member of the Bear Lake Formation at Cape Aliaksin, about 170 km northeast of Cape Tachilni (MacNeil, 1967, as "cf.", and 1973). Kanno (1971, p. 49) figured specimens of *C.* (*S.*) *donmilleri* from the "lower" Yakataga Formation of the Yakataga district, and Addicott, Winkler, and Plafker (1978) cited an occurrence in the Yakataga Formation of the Lituya district, to which they questionably assigned a Wishkahan age. Specimens of *C.* (*S.*) *donmilleri* from the Unga Conglomerate have been assigned to *C.* (*S.*) *cosibensis cosibensis* by Masuda (1972, p. 400; 1978, p. 199–200), whereas those from the Yakataga Formation of the Yakataga district have been referred by Masuda (1972, p. 400) to *Swiftopecten swiftii* (Bernardi, 1858). *Chlamys* (*Swiftopecten*) *swiftii* and *C.* (*S.*) *cosibensis cosibensis* are very similar in form and sculpture, and relationships between the two taxa have been discussed by MacNeil (1967) and Masuda (1972, 1978). *Swiftopecten swiftii* has an extensive distribution in Neogene deposits of California (Grant and Gale, 1931, p. 171–175), Japan (Masuda, 1962, p. 196), and adjacent regions of the North Pacific.

There are numerous records of *C.* (*S.*) *cosibensis cosibensis* in Miocene and Pliocene faunas of Japan (Masuda, 1959, 1962), Miocene deposits of Saishu Island, Korea (Masuda, 1962), and Sakhalin (Krishtofovich, 1964) and Kamchatka (Slodkewitsch, 1938a, 1938b; Ilyina, 1963), U.S.S.R. Masuda (1962, 1978) gives the North Pacific stratigraphic range of *C.* (*S.*) *cosibensis cosibensis* as middle Miocene to lower Pliocene, and he reports Japanese occurrences as old as early Miocene or possibly late Oligocene (Masuda, 1959, 1972, 1978) for the presumed ancestral subspecies, *C.* (*S.*) *cosibensis hanzawae* Masuda, 1959. There are no undoubted Pliocene occurrences of *C.* (*S.*) *cosibensis cosibensis* in Alaska, and Masuda's (1978, p. 200) assignment of the Unga Conglomerate Member of the Bear Lake Formation to the Pliocene, based solely on the presence of sculptural variants of the nominate subspecies, is not accepted herein. Specimens of *C.* (*S.*) *cosibensis cosibensis* occur at several USGS localities on the Alaska Peninsula in outcrops of the unnamed upper member of the Bear Lake Formation, which is of middle or late Miocene age.

All occurrences of *C.* (*S.*) *cosibensis, s.l.,* in Sakhalin and Kamchatka appear to be of Miocene age. In western Kamchatka, *C.* (*S.*) *cosibensis, s.l.,* is reported by Slodkewitsch (1938b, p. 108, as "*Pecten* (*Chlamys*) *turpiculus* Yokoyama, 1925") in the "lower horizon" of the Kavran Group, an interval now approximately equated with the Kakert Formation and assigned a middle Miocene age (Menner, Baranova, and Zhidkova, 1977; Gladenkov, 1980). Also in western Kamchatka Ilyina (1963, p. 94–95) reported "*Chlamys turpiculus*" in the Etolon Formation of the Kavran Group, strata assigned by Menner, Baranova, and Zhidkova (1977) to the early late Miocene.

The complex of *C.* (*S.*) *cosibensis* subspecies and related species occurring in Neogene strata of Kamchatka and adjacent regions of the northwestern Pacific was discussed extensively by Sinel'nikova (1975). For *C.* (*S.*) *cosibensis cosibensis* Sinel'nikova (1975, p. 66) cited occurrences in the Kakert and Etolon Formations of western Kamchatka and the "promontory Uandi" Formation (of unknown age) of Sakhalin. The Kakert and Etolon occurrences also have been noted by Slodkewitsch (1938a, 1938b), Ilyina (1963) and Gladenkov (1977). Occurrences in four formations in

the Kuril Islands are reportedly of "Miocene and Pliocene" age (Zhidkova, 1972, p. 107).

Three Tachilni specimens of *C. (S.) cosibensis cosibensis* have their valves articulated and closed, and other specimens consist only of disarticulated valves. Together with the numerous other intact shells of Tachilni bivalves, these two specimens of *Chlamys* help to demonstrate that Tachilni mollusks were preserved *in situ* and have not been greatly displaced downslope or along shore. The evidence for this provided by a mobile epifaunal bivalve such as *C. (S.) cosibensis cosibensis* is especially compelling, because such an organism is one most likely to be disarticulated and transported by waves, currents, and downslope movements.

Type information.—Holotype: TUE, registration number unknown (Masuda, 1962). Type locality: sea cliff of Shiba, Kanazawa-machi, Yokohama City, Kanagawa Prefecture, central Honshu, Japan; latitude 35°20′05″N, longitude 139°38′06″W; Koshiba Formation; Miocene (Yokoyama, 1911; Masuda, 1962).

Tachilni Formation occurrence.—USGS localities M309 (1 valve), M4044 (4 valves), M5163 (abundant fragments), M7139 (1 articulated, closed specimen, 5 valves), M7140 (1 valve, as "?"), M7141 (1 valve), M7146 (3 valves); UA locality A-170 (1 articulated, closed specimen); CAS localities 60278 (1 fragment, as "cf."), 60279 (1 articulated, closed specimen).

Figured specimens.—USNM 339757, 339758, 339759, 339760; UA 2473.

Stratigraphic and geographic range.—This subspecies is widely reported in numerous Miocene and Pliocene formations of the northwestern Pacific, with most occurrences summarized by Masuda (1962). Most occurrences are on Honshu and Hokkaido, Japan (Masuda, 1962), but it is also reported in Neogene faunas of Sakhalin (Zhidkova, 1972; Masuda, 1973), the Kuril Islands (Zhidkova, 1972), and western Kamchatka (Slodkewitsch, 1938a, 1938b; Ilyina, 1963; Sinel'nikova, 1975). Russian records include the Kakert (middle Miocene) and Etolon (lower upper Miocene) Formations of western Kamchatka (Ilyina, 1963), and the Nutovo and Maruyama Formations (lower upper Miocene) of Sakhalin (Zhidkova, 1972). Alaskan records include the Unga Conglomerate Member (MacNeil, 1967, 1973; USGS collections) and unnamed upper member (Marincovich *in* Detterman, Yount, and Case, 1981; USGS collections) of the Bear Lake Formation, Alaska Peninsula, and the Yakataga Formation of the northeastern Gulf of Alaska (Addicott, Winkler, and Plafker, 1978; USGS collections). All Alaskan records appear to be of about middle to late Miocene age, with no certain Pliocene occurrences.

Genus **MIZUHOPECTEN** Masuda, 1963

Mizuhopecten mollerensis (MacNeil, 1967)

Plate 14, figure 18

Fortipecten mollerensis MacNeil, 1967, p. 43, pl. 4, fig. 1, pl. 5, figs. 1, 6.

Mizuhopecten mollerensis (MacNeil). Masuda, 1978, p. 199.

Discussion.—This is the largest Tertiary pectinid from the Alaska Peninsula, and is represented in the Tachilni fauna by several incomplete specimens. As noted by MacNeil (1967), the left valve bears about 16 low, rounded ribs separated by interspaces nearly twice as wide as the ribs, and the interspaces lack riblets or microsculpture. Ribs on the right valve are relatively broader, sometimes flat-topped, and separated by interspaces of equal or lesser width. MacNeil (1967) had no well-preserved right valves to study, but right valves now in USGS collections bear about 18 ribs. The fourth or fifth rib from the anterior and posterior ends is only about half the width of the other ribs on the right valve. *Mizuhopecten mollerensis* is conspicuous in Alaska Peninsula Miocene faunas because of its large size, but it is known from few specimens, most of which are not well preserved. As a result, its range of morphologic variation is not well known.

Mizuhopecten ranges from Oligocene to Holocene in Japan (Masuda, 1978, p. 198), but is reported only in upper Miocene faunas of western North America (Addicott, 1981, p. 24). MacNeil (1967) tentatively considered *M. mollerensis* to be of late Miocene age, based on a single occurrence in the Bear Lake Formation near Port Moller (Text-fig. 2). The species has since been found at several Bear Lake Formation localities of presumed middle or late Miocene age (Marincovich *in* Detterman, Yount, and Case, 1981). Its earliest possible occurrence is in strata thought to belong to the Unga Conglomerate Member of the Bear Lake Formation near Port Moller (K. Masuda, written commun., 1982; USGS coll.), of early or middle Miocene age.

Type information.—Holotype: USNM 645047. Paratype: USNM 645048. Type locality: USGS M2131, "A small knob extending above the level of the Recent terrace on the south shore of Port Moller, approximately 3 miles southeast of Point Divide" (MacNeil, 1967, p. 43), Alaska; Bear Lake Formation; middle or upper Miocene.

Tachilni Formation occurrence.—USGS localities M7144 (fragments), M7149 (12 valves), M7150 (2 valves).

Figured specimen.—USNM 339761.

Stratigraphic and geographic range.—Known only in Miocene rocks of the Alaska Peninsula. Lower or middle Miocene: Unga Conglomerate Member (?) of

Bear Lake Formation near Port Moller (K. Masuda, written commun., 1982; USGS collections). Middle or upper Miocene: unnamed upper member of Bear Lake Formation, at several localities between Port Heiden and Port Moller (Marincovich *in* Detterman, Yount, and Case, 1981).

Family **CARDITIDAE** Fleming, 1828

Genus **CYCLOCARDIA** Conrad, 1867

Cyclocardia cf. **C. roundiformis** (Ilyina, 1963)
Plate 14, figures 3–8

Cardita roundiformis Ilyina, 1963, p. 98–99, pl. 34, fig. 3.

Discussion.—Tachilni specimens tentatively assigned to this species have relatively small, nearly equidimensional shells bearing about 28 radial ribs of very low relief. The radial ribs are separated by much narrower interspaces and crossed by fine concentric growth lines that may produce weak nodes on the ribs. The umbo is distinctly elevated and adult shell height is equal to or slightly greater than its length. The anterior dorsal margin is shallowly concave, and the posterior dorsal margin is slightly convex. Based on five well-preserved Tachilni adults, the average length is 19.7 mm and average height 20.1 mm. The largest specimen has a length of 20.6 mm and height of 21.2 mm. A juvenile specimen from locality M7139 has 31 ribs and is only questionably included with the other Tachilni specimens.

It is impossible to assign Tachilni specimens confidently to *C. roundiformis* for two reasons: Ilyina's species is known to me only from one illustration accompanying the original description (which was based on three specimens), and there are dozens of described North Pacific Oligocene to Holocene species of *Cyclocardia* of roughly similar morphology. *Cyclocardia roundiformis* was characterized as having a small shell with rounded outline, elevated umbo, and 28 to 30 low radial ribs separated by fine interspaces (Ilyina, 1963). Dimensions of the holotype were given as length 23.7 mm and height 23.3 mm. Thus, by their shell size and proportions, and the number and low relief of their ribs, the Tachilni specimens closely resemble *C. roundiformis*.

Cyclocardia roundiformis is evidently known only from its type locality in western Kamchatka. A citation by Ariey (1978, p. 78–79) of "*Cyclocardia* sp. nov.? cf. *C. roundiformis* (Ilyina)" from upper Oligocene or lower Miocene rocks of the Poul Creek Formation at Yakataga Reef, northeastern Gulf of Alaska, refers to a different species. The single specimen referred to by Ariey (1978), which I have examined, has 30 or 31 radial ribs with trigonal cross-sections.

The bathymetric range of living species of *Cyclocardia* from western North America is reported as intertidal to 2,211 m (Keen and Coan, 1974; Coan, 1977). The genus is well known in the Arctic Ocean and ranges in the eastern Pacific at least as far south as Panama (Keen, 1971, p. 109). Reports of the genus as far south as northern Chile (Olsson, 1961; Keen, 1971) need confirmation.

Type information.—Holotype (of *C. roundiformis*): "No. 93/6338" (Ilyina, 1963; repository uncertain). Type locality: "between the Etolon River and Nepropusk," western Kamchatka, U.S.S.R. (Ilyina, 1963); Etolon Formation of the Kavran Group; upper Miocene age.

Tachilni Formation occurrence.—USGS localities M7139 (2 articulated, closed specimens, 3 valves), M7146 (1 articulated, closed specimen); UA locality A-170 (1 articulated, closed specimen).

Figured specimens.—USNM 339762, 339763; UA 2474, 2500.

Stratigraphic and geographic range.—*Cyclocardia roundiformis* is known only from its type locality.

Cyclocardia sakamotoi new species
Plate 14, figures 12–14

Diagnosis.—Shell large for the genus, with a rounded trigonal shape, nearly central umbones with straight dorsal margins, and 10 major radial ribs on each valve.

Description.—This species is characterized by a rounded trigonal shell that is large for the genus and bears 10 major radial ribs on each valve. In addition, four or five obscure radial riblets occur to either side of the major radial ribs and lie approximately parallel to the adjacent dorsal margins. The major ribs are raised in high relief, are rounded to somewhat trigonal in cross-section, and are separated by interspaces about half their width. These ribs produce a sinuous commissure along the ventral shell margin. Concentric sculpture consists of fine growth lines that have a minutely wrinkled appearance. The nearly central umbo is moderately elevated and the major portions of both the anterior and posterior dorsal margins are virtually straight. Due to the long and straight posterior dorsal margin, the posterior end of the shell is narrowly rounded for the genus. The escutcheon is lanceolate and extends for half the length of the posterior dorsal margin. The lunule is elongate but narrow and indistinct. The holotype is 34.0 mm in length, 30.5 mm in height, and 14.7 mm in thickness (both valves).

Discussion.—*Cyclocardia sakamotoi* is distinguished from the many other North Pacific Cenozoic species of *Cyclocardia* by its large size, few strong radial ribs, straight dorsal margins and nearly central umbo, and its rounded trigonal shape. Among Pleis-

tocene and Holocene species, only *C. crassidens* (Broderip and Sowerby, 1829) seems to grow as large as *C. sakamotoi* and also to have relatively few radial ribs. However, the nearly circular shape and more numerous (12 to 16) radial ribs (Coan, 1977) of *C. crassidens* clearly separate it from the Tachilni species.

Surprisingly, among the large number of described North Pacific Tertiary species of *Cyclocardia,* there seems to be no species that could easily be confused with *C. sakamotoi*. However, there are some Miocene taxa, especially those described from Kamchatka (Slodkewitsch, 1935, 1938a, 1938b; Ilyina, 1963), that resemble *C. sakamotoi* in their large size and few radial ribs. The most similar among these are *C. kavranensis* (Slodkewitsch, 1935), with seven to nine ribs, and *C. etalonnensis* (Slodkewitsch, 1935), with 11 to 12 ribs, both described from the upper Miocene Etolon Formation of western Kamchatka. Slodkewitsch's two species are distinct from *C. sakamotoi* by having rounded outlines lacking any trigonal aspect, umbones that are on the anterior third of the shell rather than being subcentral, strongly convex posterior dorsal margins and moderately concave anterior dorsal margins rather than virtually straight margins, curved rather than straight radial ribs, and strongly prosogyrate beaks. The two Kamchatkan species share similar shell outlines and large size with *C. crassidens*, and may lie in the ancestral lineage of that species.

The fragmentary Tachilni specimen referred to herein as *Cyclocardia* sp. A is similar in size to *C. sakamotoi,* but differs by having strongly prosogyrate beaks and a moderately concave anterior dorsal margin. The total rib-counts of the two taxa are similar, but the large ribs of *C.* sp. A become progressively narrower toward the shell ends, whereas the major ribs of *C. sakamotoi* end abruptly near the dorsal margins and are succeeded by poorly developed riblets.

Etymology.—This species is named for Kenji Sakamoto, photographer for the Branch of Paleontology and Stratigraphy, U.S. Geological Survey, Menlo Park, California, whose fine photographs of fossils have enhanced many publications.

Type information.—Holotype: USNM 339764. Type locality: USGS M7139, at the type locality of the Tachilni Formation, Cape Tachilni, Alaska Peninsula, Alaska; collected by L. Marincovich, Jr., June 1977.

Tachilni Formation occurrence.—USGS locality M7139 (1 articulated, closed specimen); CAS locality 60279 (1 articulated, closed specimen).

Figured specimen.—USNM 339764 (holotype).

Stratigraphic and geographic range.—Known only from the type locality.

Cyclocardia species A
Plate 14, figures 9, 10

Discussion.—Two incomplete specimens, one articulated, represent a large species of *Cyclocardia* different from other Tachilni species of this genus. The articulated specimen is 30.8 mm long, but may have been about 35 mm long before its posterior portion was lost. Twenty rounded-trigonal radial ribs are preserved on each valve. The middle 12 ribs are most strongly developed, with four progressively narrower ribs on each side of these. The interspaces are one-fourth or less the width of the ribs. Fine, irregularly spaced concentric growth lines are most strongly developed ventrally. The umbones are moderately elevated, the anterior dorsal margin is moderately concave, and the posterior dorsal margin is slightly convex.

The fragmentary Tachilni specimen is closest in size and sculpture to two Miocene species described from western Kamchatka, *C. kamtschatica* (Slodkewitsch, 1935) and *C. kamtschatica dvalii* (Slodkewitsch, 1938a). The main differences between Slodkewitsch's two taxa are that the former is larger (length 35 to 40 mm, versus 33 to 35 mm) and has more numerous radial ribs (24 to 25, versus 20 to 23) than the latter (Slodkewitsch, 1935, 1938a, 1938b). The Tachilni specimen is clearly more similar to *C. kamtschatica dvalii,* which is known from upper Miocene rocks of the Etolon Formation in western Kamchatka (Slodkewitsch, 1938a, 1938b; Ilyina, 1963). Additional Tachilni specimens are needed for a more certain identification. As noted in the discussion of *C. sakamotoi,* that species also resembles *Cyclocardia* species A.

Tachilni Formation occurrence.—USGS locality M7149 (1 valve); UA locality A-169 (1 articulated adult).

Figured specimen.—UA 2475.

Genus **MIODONTISCUS** Dall, 1903

Miodontiscus prolongatus (Carpenter, 1864b)
Plate 14, figure 11

Miodon prolongatus Carpenter, 1864b, p. 642.
Venericardia yatesi Arnold, 1907, p. 21–22, pl. 58, figs. 2a, 2b.
Venericardia (*Miodontiscus*) *prolongatus* (Carpenter). Oldroyd, 1924, vol. 1, p. 115, pl. 2, figs. 5, 6.
Cardita (*Miodontiscus*) *prolongatus* (Carpenter). Grant and Gale, 1931, p. 276 [contains extensive synonymy].
Cardita (*Miodontiscus*) *prolongata* (Carpenter). Slodkewitsch, 1938a, p. 336–339; Slodkewitsch, 1938b, p. 146–147, pl. 66, figs. 5–9.
Miodontiscus prolongatus (Carpenter). Palmer, 1958, p. 83–84, pl. 8, figs. 1–7; Hertlein and Grant, 1972, p. 233–234, pl. 56, figs. 1–5.

Discussion.—The single valve of this species in the Tachilni fauna, with a height of 7.0 mm and length of

6.2 mm, has the typically small size and elevated proportions of *Miodontiscus*. The few radial ribs (13), which are flattened and separated by narrowly incised interspaces, as well as widely spaced, incised concentric lines, are characteristic of *M. prolongatus*.

Carpenter (1864b, p. 424) cited 10–12 radial ribs for Holocene specimens of *M. prolongatus*. Slodkewitsch (1938a, p. 336) reported 8–12 ribs for Kamchatkan Miocene specimens [the "18–21" ribs cited in Slodkewitsch, 1938b, p. 146, is a typographical error], and Arnold (1907, p. 21) noted 8–9 ribs for Californian Pleistocene specimens of *M. yatesi,* a synonym. Thus, the presence of 13 radial ribs on the Tachilni specimens increases by one the rib-count of *M. prolongatus* as reported in the literature.

Miodontiscus has not been reported before as a fossil in Alaska, though fossils are known from California and Kamchatka. The oldest reported occurrence of *M. prolongatus* is in the upper Miocene Cebada Fine-Grained Member of the Careaga Sandstone and the lower Pliocene Foxen Mudstone in the Santa Maria District of southern California (Woodring and Bramlette, 1950, p. 65; as "cf."), although the species is best known as a fossil in Pleistocene deposits of southern California (Grant and Gale, 1931).

Slodkewitsch (1938b, p. 147) was the first to synonymize *M. yatesi* (Arnold, 1907), a species described from the lower Pleistocene Santa Barbara Formation of southern California, with *M. prolongatus,* and Woodring and Bramlette (1950, p. 86) concurred in this opinion. Slodkewitsch (1938b, p. 147) further suggested that *M. nakamurai* (Yokoyama, 1926), described from the Pliocene Sawane Formation of Honshu, may be a synonym of *M. prolongatus*. Coan (1977, p. 384) also noted the close similarity of *M. prolongatus* and *M. nakamurai*. Another closely related taxon is *M. nakamurai annakensis* (Oinomikado, 1938), described from the Miocene Itahana Formation of Honshu.

Type information.—Syntypes: USNM 15472 (5 specimens); Redpath Museum, McGill Univ., No. 2377 (4 specimens) (Palmer, 1958, p. 83–84). Type locality: Neah Bay, northwestern Washington; Holocene.

Tachilni Formation occurrence.—USGS locality M7142 (1 valve).

Figured specimen.—USNM 339765.

Stratigraphic and geographic range.—This species is known in upper Miocene to Holocene faunas. Upper Miocene: Cebada Fine-Grained Member of the Careaga Sandstone, Santa Maria District, southern California (Woodring and Bramlette, 1950, as "cf."); Etolon Formation (?) of Kavran Group, on coastline near mouth of Etolon River, western Kamchatka (Slodkewitsch, 1938a, 1938b). Lower Pliocene: Foxen Mudstone, Santa Maria District, southern California (Woodring and Bramlette, 1950). Lower Pleistocene: Santa Barbara Formation, Santa Barbara, southern California (Arnold, 1907, as *M. yatesi*); Lomita Marl Member, Timms Point Silt Member, and unnamed sand member of San Pedro Formation, San Pedro, southern California (Woodring, Bramlette, and Kew, 1946). Upper Pleistocene: Palos Verdes Sand, Newport Bay, southern California (Kanakoff and Emerson, 1959). Holocene: Middleton Island, central Gulf of Alaska, to San Diego, California (Dall, 1921), in depths of 9–55 m (Burch, 1944, no. 39, p. 17).

Family **UNGULINIDAE** H. & A. Adams, 1857

Genus **FELANIELLA** Dall, 1899

Felaniella parilis (Conrad, 1848)

Plate 14, figures 15–17

Loripes parilis Conrad, 1848, p. 432, fig. 7.
Diplodonta parilis (Conrad). Dall, 1900, p. 1182; Arnold, 1909, p. 140, pl. 17, fig. 5; Hickman, 1969, p. 42–43, pl. 3, figs. 2, 3, 5–7.
Diplodonta (*Felaniella*) *parilis* (Conrad). Dall, 1909, p. 117, pl. 11, fig. 6.
Taras parilis (Conrad). Grant and Gale, 1931, p. 294.
Taras (*Felaniella*) *parilis* (Conrad). Slodkewitsch, 1938a, p. 367–369; Slodkewitsch, 1938b, p. 151, pl. 73, figs. 8–10.
Felaniella parilis (Conrad). Addicott, 1976a, p. 107, pl. 3, fig. 9.

Discussion.—This species is characterized by its nearly circular outline with prominent umbones, thin shell, and somewhat compressed valves. It is a large species for the genus, and the largest Tachilni specimen, at 22.8 mm long and 20.5 mm high, is not an uncommon size for *F. parilis*.

This species is well known in northeastern Pacific Tertiary faunas, but its taxonomic relationsips and stratigraphic range are uncertain. As Hickman (1969, p. 42) noted, "*Diplodonta parilis* has traditionally been regarded as a Miocene and Pliocene species, although it seems to be part of a complex of similar forms which appears in the Oligocene and extends into the Recent." The stratigraphic range of this complex has lately been extended into probable upper Eocene strata of the Pittsburgh Bluff Formation in Oregon (Moore, 1976, p. 46–47). The presence of *F. parilis* in Holocene faunas is based on its synonymy with *F. sericata* (Reeve, 1850), which is reported to range from Monterey Bay, California, to northern Peru (Keen, 1971, p. 129). Addicott (1976a, p. 107) cited the stratigraphically highest Pacific Northwest occurrence of *F. parilis* in Wishkahan faunas, but the biostratigraphic utility of the species will be in doubt until eastern Pacific Cenozoic species of *Felaniella,* of which at least a dozen have been named, are better known.

Keen (1971, p. 129) states that *F. sericata,* which is at the very least the modern homologue of *F. parilis,* "may be found intertidally, but more commonly . . . in depths to 75 m on sand or mud bottoms."

Type information.—Holotype: ANSP, No. 4546 (figured by Moore, 1962, p. 111, pl. 23, fig. 9). Type locality: Astoria, Oregon; Astoria Formation; middle Miocene.

Tachilni Formation occurrence.—USGS localities M7139 (1 articulated, closed specimen), M7142 (1 valve); UA localities A-169 (1 valve), UA A-170 (1 articulated, closed specimen).

Figured specimens.—USNM 339766; UA 2476.

Stratigraphic and geographic range.—Felaniella parilis belongs to a species-complex that ranges from about late Eocene to Holocene and within which taxonomic relationships are unclear. There are numerous northeastern Pacific records in late Eocene and younger strata (Grant and Gale, 1931; Keen and Bentson, 1944; Moore, 1963; Hickman, 1969), and Addicott (1976a) gives its highest occurrence in Pacific Northwest strata in Wishkahan faunas. This species is also reported in the "upper Kavran" Group of western Kamchatka by Slodkewitsch (1938a, 1938b), in strata now referred to the Kakert and Etolon Formations (Ilyina, 1963) and assigned an age of late middle to early late Miocene (Menner, Baranova, and Zhidkova, 1977; Gladenkov, 1980). Also reported by Slodkewitsch (1938a, 1938b) in the "Machigar section" of the Schmidt Peninsula, northern Sakhalin, strata now referred to the Machigar Formation of Oligocene age (Gladenkov, 1980, p. 1090).

Family **CHAMIDAE** Blainville, 1825

Genus **CHAMA** Linnaeus, 1758

Chama sp.?

Discussion.—A single imperfectly preserved valve that may represent *Chama* was found at UA locality A-170. The valve is roughly circular in outline, about 30 mm in diameter, and is cemented into a depression in the attached matrix. The hinge area is missing, but sculpture of fine, closely-spaced, irregular radial costellae and coarse concentric laminae is reminiscent of several eastern Pacific species of *Chama* and *Pseudochama* Odhner, 1917 illustrated by Bernard (1976).

Chamids are most diverse and abundant in the tropics, but some species occur in cool-temperate habitats. In the modern eastern Pacific, *Chama arcana* Bernard, 1976, ranges to 44°N latitude in Oregon (Bernard, 1976, p. 15), and *C. pellucida* Broderip, 1835, occurs at 33°S latitude in the Juan Fernandez Islands, Chile (Marincovich, 1973, p. 11). As noted by Bernard (1976, p. 2), most chamids inhabit exposed shorelines and cannot tolerate lowered salinity or high sedimentation rates; maximum abundance is just subtidal, though a few species occur to 200 m depth.

The Tachilni specimen is not suitable for illustration. Living or fossil species of *Chama* have not previously been reported from Alaska, and the confirmation of the presence of the genus in the Tachilni fauna requires further collecting.

Family **CARDIIDAE** Lamarck, 1809

Genus **CLINOCARDIUM** Keen, 1936

Clinocardium cf. **C. ciliatum** (Fabricius, 1780)
Plate 15, figure 1

Cardium ciliatum Fabricius, 1780, p. 410; Dall, 1904, p. 113.
Laevicardium (*Cerastoderma*) *ciliatum* (Fabricius). Grant and Gale, 1931, p. 310, pl. 19, fig. 11.
Clinocardium ciliatum (Fabricius). Clench and Smith, 1944, p. 15–16, pl. 10; Kennedy, 1978, p. 440–441.
Ciliatocardium ciliatum (Fabricius). Kafanov, 1980, p. 310, 312.

Discussion.—This living circumarctic species is represented in the Tachilni fauna by two specimens. The best-preserved specimen is an external cast of a right valve, subcircular in outline, 21.5 mm long by 18.4 mm high, and with 28 trigonal ribs (probably with another two or three ribs not preserved). The specimen is smaller than average for adults of *C. ciliatum,* and its poor state of preservation does not permit more certain identification.

This species is among the most common living northern bivalves, ranging throughout the Arctic Ocean and the high-latitude North Pacific and North Atlantic (Bernard, 1979a, p. 45). The subcircular to ovate, thin, inflated shell with trigonal ribs is distinctive among living bivalves of this region. However, the species has been named several times (see synonymy in Dall, 1901) because the number of radial ribs varies greatly among individuals. Kafanov (1980, p. 310) claimed that the rib-count may vary from 20 to 50, although a more frequently stated range is 28 to 40 (Bernard, 1979a, p. 45). This was the only living species assigned to *Ciliatocardium* when Kafanov (1974, p. 1469) proposed the genus, though he later added two living Atlantic subspecies and one Japanese Pliocene subspecies (Kafanov, 1980, p. 311–313). In addition, Kafanov (1980) recognized 16 extinct North Pacific species he placed in *Ciliatocardium,* nearly all of which are described from Japan, Sakhalin and Kamchatka, the oldest of which is Oligocene. Of these 16 Tertiary species two, *C. brooksi* (Clark, 1932) and *C. yakatagense* (Clark, 1932), were reported from Alaska, in the Poul Creek and Yakataga Formations in the northeastern Gulf of Alaska (Clark, 1932; Kanno, 1971). *Clinocardium ya-*

katagense differs from *C. ciliatum* by having a strongly elevated shell and only about 24 distinct radial ribs that are not trigonal (Kanno, 1971, p. 67). *Clinocardium brooksi,* however, is similar in shape, size, rib-count and rib shape to *C. ciliatum,* and differences between the two taxa are not well defined. The former species is known from the upper Poul Creek (Clark, 1932; Addicott *et al.,* 1971) and lower Yakataga (Kanno, 1971) Formations of the Yakataga district, northeastern Gulf of Alaska, in beds of about early Miocene age. The oldest records of *C. ciliatum* are in presumed middle Miocene beds of the Maruyama Formation of Sakhalin (Kafanov, 1980, p. 312). The present tentative report of *C. ciliatum* in the Tachilni Formation is the oldest one claimed for Alaska, unless *C. brooksi* is considered conspecific.

Clinocardum ciliatum has been reported living most often in outer shelf depths. Clench and Smith (1944, p. 16) cite this species in 183 m off Labrador, although most of their northwestern Atlantic records are in depths of about 35 to 100 m. Living specimens have been found at 33 m off Point Barrow, Alaska (MacGinitie, 1959, p. 176), and in depths of 26 to 159 m in the western Beaufort Sea (Bernard, 1979a, p. 45). In the Gulf of Alaska region records range from about 22 to 91 m (Burch, 1944), and the species is reported in the eastern Pacific as far south as Puget Sound (Dall, 1921). The latter record requires confirmation because Bernard (1979a) gives no eastern Pacific records south of the northern Gulf of Alaska.

Type information.—Lectotype: UZM, no registration number (designated by Kafanov, 1980, p. 312). Type locality: Greenland; Holocene.

Tachilni Formation occurrence.—USGS localities M7146 (1 valve), M7256 (1 valve).

Figured specimen.—USNM 339767.

Stratigraphic and geographic range.—This species ranges from middle (?) or upper Miocene to Holocene. Middle (?) Miocene: lower part of Maruyama Formation, Sakhalin (Kafanov, 1980). Upper Miocene: Komeutiyama Formation of the Koryak Upland; Okobykayska Formation, northern Sakhalin (Kafanov, 1980); Alekhinska, Kamuyska, and Golovninsk Formations of Kuril Islands (Zhidkova, 1972; Kafanov, 1980); Utsutoge Formation, northern Honshu, Japan (Kafanov, 1980). Reported also in Pinakul and Crestov Formations of Chukotka, U.S.S.R., from faunas of unknown age (Zhidkova, 1972, as "cf."). Reported from unknown formation on Popof Island, western Gulf of Alaska (Dall, 1904, p. 113), where marine strata are of Oligocene and Miocene age (Burk, 1965). Pliocene and Pleistocene: numerous records throughout the North Pacific (Grant and Gale, 1931; Kennedy, 1978; Kafanov, 1980). Holocene: Circumarctic and circumboreal. In the Pacific, modern records cite the species as far south as northern Japan and the northern portion of the Gulf of Alaska (Bernard, 1979a), though Dall (1921) cited it at Puget Sound, Washington. Burch (1944) gave one report from Ketchikan, southeastern Alaska.

Clinocardium hannibali Keen, 1954
Plate 15, figures 2–4

Clinocardium hannibali Keen, 1954, p. 18–19, pl. 1, fig. 16, text-fig. 9; Addicott, 1976a, p. 105.
Keenocardium hannibali (Keen). Kafanov, 1980, p. 309.

Discussion.—This is the most abundant *Clinocardium* in the Tachilni Formation, although well-preserved specimens are rare. Tachilni specimens are characterized by relatively small size (averaging about 23 mm long), nearly equidimensional valves of rounded trigonal outline, and about 37 radial ribs with flat or slightly rounded tops.

Keen (1954, p. 18) gave average dimensions for this species of length 24.5 mm, height 24.5 mm, and noted that the radial ribs range in number from 35 to 40, which agrees well with the Tachilni specimens. The largest specimen cited by Keen (1954) was 42 mm long and 42 mm high, which is slightly larger than the largest Tachilni individual. There is a distinct variation in outline among the Tachilni specimens, ranging from the more orbicular to the more trigonal, but the majority match well with the figure of the holotype (Keen, 1954, pl. 1, fig. 16).

Within Tachilni strata *C. hannibali* occurs at few localities but in great numbers. It is the most abundant species in beds where it is found, occurring in jumbled accumulations of disarticulated valves. Specimens occur nearly always as molds or casts bearing scraps of shell material.

Type information.—Holotype: SUPTC, No. 8302. Paratype: SUPTC No. 8303. Type locality: SU locality NP-235, at intersection of Chehalis and Summit Streets, Aberdeen, Washington; lower part of Montesano Formation; upper Miocene.

Tachilni Formation occurrence.—USGS localities M7146, M7149, M7150, M7256 (as "cf."); UA localities A-169, A-170, A-301. Specimens are abundant at all localities.

Figured specimens.—USNM 339768, 339769.

Stratigraphic and geographic range.—The only verified records of this species are in upper Miocene faunas. Upper Miocene: Montesano Formation at Aberdeen and nearby localities, Grays Harbor County, southwestern Washington (Keen, 1954). Addicott (1976a, p. 105) regarded this species as restricted to

the Wishkahan Stage in the Pacific Northwest. Questionably reported by Allison and Marincovich (1981, as "cf.") in upper Oligocene or lowermost Miocene strata of the Narrow Cape Formation on Sitkinak Island, western Gulf of Alaska (Text-fig. 1).

Clinocardium meekianum (Gabb, 1866) new subsp.?
Plate 15, figures 5–8

Discussion.—A large species of *Clinocardium* well-represented in the Tachilni fauna does not match exactly with described taxa. The Tachilni species of *Clinocardium* is characterized by relatively large size, moderately to distinctly oblique outline, and 30 or 31 radial ribs. The radial ribs are noded and their shape grades from rounded at the anterior end of the shell to rounded-triangular at the posterior end.

The Tachilni taxon is related in shape and sculpture to *C. nuttallii* (Conrad, 1837), *C. meekianum meekianum* (Gabb, 1866), and *C. meekianum myrae* Adegoke, 1969, and contains morphological characters of all three taxa. *Clinocardium nuttallii* is the common Miocene (?) or Pliocene to Holocene northeastern Pacific (California to Washington) species, *C. meekianum meekianum* is a Miocene and Pliocene taxon in the same region, and *C. meekianum myrae* occurs in upper Miocene strata in central California.

Clinocardium nuttallii is relatively equilateral in valve outline, and *C. meekianum meekianum* and *C. meekianum myrae* are distinctly oblique, whereas the Tachilni taxon includes both morphotypes. The best-preserved Tachilni specimens have 30 or 31 noded radial ribs, whereas *C. nuttallii* has, according to various workers, 34 ribs (Keen, 1954, p. 21), "about 34–35 ribs on average" (Kafanov, 1980, p. 305), or 32 to 41 ribs (Kilmer, 1973); *C. meekianum meekianum* is said to have 28 ribs (Keen, 1954, p. 21), or 22 to 25 ribs "typically" (Adegoke, 1969, p. 118). Roth (1979, p. 303) states that *C. meekianum meekianum* has 21–27 ribs "exclusive of obscure ribs on the posterior slope," although most specimens have 22 or 23 ribs—he also names a new subspecies of *C. meekianum* having 22 to 28 ribs. Adegoke (1969, p. 118) reports 28 to 30 ribs for *C. meekianum myrae*. From these published accounts of other taxa, the Tachilni specimens of *C. meekianum*, with 30 or 31 ribs, occupy a medial position in rib-count between *C. nuttallii* and *C. meekianum meekianum*.

The radial ribs of *C. meekianum* new subsp.? clearly grade from rounded at the anterior end of the shell to rounded-triangular at the posterior end. This varying rib shape is also present in *C. nuttallii* but not, with one exception, in *C. meekianum meekianum*. For a new subspecies of *C. meekianum*, Roth (1979, p. 304) noted that in young specimens under 20 mm long the ribs are rounded-triangular in section; adult specimens, as large as 104.7 mm long and 101.4 mm high, have rounded ribs. The presence of rounded-triangular posterior ribs in *C. nuttallii* and *C. meekianum* new subsp.? is a link between the two taxa. The largest Tachilni specimen is 77.1 mm long and 66.9 mm high, and several other adults are nearly as large.

The presence of both rounded and rounded-triangular radial ribs on the Tachilni taxon brings into question Kafanov's (1974, 1980) subgeneric division of *Clinocardium*. *Ciliatocardium* was created by Kafanov (1974, 1980) for species with triangular ribs, whereas other species were placed either in *Clinocardium, s.s.*, (having transverse nodular tubercula atop the ribs) or *Keenocardium* (lacking transverse nodular tubercula of the former and the triangular shape (on posterior ribs) of the latter). The type-species of *Clinocardium, s.s., C. nuttallii*, also has rounded-triangular posterior ribs on many Holocene specimens I have examined. The value of Kafanov's subgenera is doubtful.

Tachilni Formation occurrence.—USGS localities M5169 (1 valve, as "cf."), M7140 (1 valve), M7146 (1 articulated, closed specimen, 10 valves), M7149 (1 valve), M7150 (1 articulated, closed specimen, 1 valve), M7201 (1 articulated, closed specimen); UA localities A-169 (1 valve), A-170 (2 valves), A-301 (1 articulated, closed specimen); CAS locality 60279 (1 articulated, closed specimen, 1 valve).

Figured specimens.—USNM 339770, 339771, 339772.

Stratigraphic and geographic range.—The possibly new subspecies noted here is known only in the Tachilni Formation. Addicott (1976a, p. 105) stated that in the Pacific Northwest *C. meekianum, s.l.*, has its earliest occurrence in Wishkahan faunas.

Clinocardium cf. **C. pristinum** Keen, 1954
Plate 15, figures 9–12

Clinocardium pristinum Keen, 1954, p. 16–18, pl. 1, figs. 9, 15, text-figs. 7, 8.
Keenocardium pristinum (Keen). Kafanov, 1980, p. 308, 310.

Discussion.—*Clinocardium pristinum* was characterized by Keen (1954) as having a trigonal shell with prominent umbones and 42 to 48 flattened radial ribs that tend to become obsolete on the posterior slope. The largest specimen she noted, the holotype, is 53 mm long and 50 mm high. Tachilni specimens tentatively assigned to this species are similar in shell shape, rib-count and rib shape to *C. pristinum*, but differ in size and exact configuration of the posterior dorsal margin. Five Tachilni specimens are assigned to this taxon, of which the largest is 64 mm long. The two

best-preserved specimens each have 45 radial ribs, another specimen has 42 ribs with three or four additional ribs evidently worn off, and a fourth specimen is incomplete and shows only 29 ribs. Where the radial ribs are well-preserved they are flat-topped or very slightly rounded and are separated by much narrower interspaces.

The only obvious difference bewteen typical *C. pristinum* and the Tachilni specimens is in the shape of the posterior dorsal margin. On Tachilni specimens this margin is nearly straight or slightly convex and rounds smoothly into the posterior margin, whereas Keen's (1954) photos of *C. pristinum* show the posterior dorsal and posterior margins meeting at an angle of 140°. A large sampling of specimens from Alaska and California might show this to be a gradational feature, but for now caution seems justified in applying this species name to Tachilni specimens.

The species most similar in form to *C. pristinum* is *C. hopkinsi* Kanno, 1971, described from upper Oligocene or lower Miocene beds of the Poul Creek Formation in the Cape Yakataga area, Gulf of Alaska (Text-fig. 1). Kanno's (1971) species is characterized by having about 40 flattened or slightly rounded radial ribs with cross-threads that tend to crowd together toward the ventral margin, and he listed his largest specimen as 50 mm long and 42 mm high. The holotype of *C. hopkinsi* has a gently convex posterior dorsal margin that merges smoothly with the posterior margin (Kanno, 1971, pl. 5, fig. 7a), whereas the paratype has an angulate juncture of the posterior dorsal and posterior margins (a possible artifact of preservation).

Another taxon similar in size and form to the Tachilni species is *C. lispum* Roth and Talmadge, 1975, described from the Pliocene Rio Dell Formation of northern California. The holotype of *C. lispum*, however, has 59 radial ribs that clearly distinguish it from the Tachilni species.

Type information.—Holotype: UCMP, No. 14838. Type locality: southwest part of Shell Ridge, near Walnut Creek, Contra Costa County, northern California; "San Pablo Group, probably Neroly formation" (Keen, 1954, p. 17); upper Miocene.

Tachilni Formation occurrence.—USGS localities M7140 (1 valve), M7146 (3 valves), M7256 (1 valve), M7258 (1 valve).

Figured specimens.—USNM 339773, 339774, 339775, 339776.

Stratigraphic and geographic range.—This species is known for sure only in upper Miocene strata. Upper Miocene: San Pablo Group, Neroly Formation, Contra Costa County, northern California (Keen, 1954). It questionably occurs in middle Miocene beds of the Astoria Formation, southwestern Washington (Keen, 1954).

Family **VENERIDAE** Rafinesque, 1815

Genus **SAXIDOMUS** Conrad, 1837

Saxidomus sp. indet.
Plate 15, figure 13

Discussion.—*Saxidomus* is represented by a single articulated, closed individual in the Tachilni fauna. The specimen is 68.9 mm long and 52.2 mm high, of average size for an adult of this genus, and the thick shell and rounded quadrate shell outline further suggest *Saxidomus*. Remnants of the exterior shell surface have fine concentric growth lines as the only sculpture, so the intact shell may have had a fairly smooth surface texture.

Its state of preservation does not allow a reliable species assignment, but the Tachilni specimen is most similar to *S. giganteus* (Deshayes, 1839), known from upper Miocene to Holocene faunas of the northeastern Pacific (Addicott, 1978; Fitch, 1953).

Living species of *Saxidomus* in the northeastern Pacific are reported in depths from the intertidal zone to 35 m, in substrates of sand and mud (Keen and Coan, 1974).

Tachilni Formation occurrence.—USGS locality M7139 (1 articulated, closed specimen).

Figured specimen.—USNM 339777.

Genus **PROTOTHACA** Dall, 1902

Subgenus **PROTOTHACA** Dall, 1902

Protothaca (Protothaca) staleyi (Gabb, 1866)
Plate 16, figures 1–4

Dosinia staleyi Gabb, 1866, p. 24, pl. 7, fig. 42.
Tapes staleyi (Gabb). Gabb, 1869, p. 57, pl. 16, figs. 17, 17a.
Paphia staleyi (Gabb). Arnold, 1909, p. 25 [as "?"], p. 27 [as "?"], p. 31 [as "?"], p. 35, 39, pl. 26, fig. 8 [as "?"]; Arnold and Anderson, 1910, p. 109, 110, 112, 126 [all as "?"], 129, 132, pl. 48, fig. 8 [as "?"].
Venerupis (*Protothaca*) *staleyi* (Gabb). Stewart, 1930, p. 222–223, pl. 15, fig. 4.
Protothaca staleyi (Gabb). Addicott, 1969, p. 73–74, pl. 2, figs. 5, 6, 8, pl. 4, fig. 1.

Discussion.—The shell of this species is subquadrate, thick-walled, and strongly inflated. Sculpture consists of fine, subdued radial costellae, and fine, closely but irregularly spaced concentric growth lines. The radial and concentric sculpture are of approximately equal strength, although the concentric lines seem to be slightly stronger in places. The relatively great thickness of the shell is shown well on a broken left valve (Pl. 16, fig. 1), in which the shell near the posterior ventral margin is nearly 4 mm thick.

This species is similar in appearance to several other late Cenozoic species of *Protothaca* of western North America. The most common living species in this region, *P.* (*P.*) *staminea* (Conrad, 1837), is of about the same size as *P.* (*P.*) *staleyi,* but has a less quadrate outline, a much thinner and less inflated shell, and radial sculpture that is distinctly stronger than the concentric lines. In addition, the radial costellae of *P.* (*P.*) *staminea* become broader anteriorly, which does not happen in *P.* (*P.*) *staleyi*. Another related living species is *P.* (*P.*) *laciniata* (Carpenter, 1864a), which at a length of 50 to 80 mm (McLean, 1978, p. 79) is larger than *P.* (*P.*) *staleyi*. The valves of *P.* (*P.*) *laciniata* are subquadrate, thick, inflated, and have evenly developed sculpture across the entire shell surface, as in *P.* (*P.*) *staleyi*. However, the well-developed radial and concentric sculpture of *P.* (*P.*) *laciniata* intersect to form a rasp-like surface (McLean, 1978, p. 79), which does not happen in *P.* (*P.*) *staleyi* and is not present on Tachilni specimens. *Protothaca* (*Protothaca*) *laciniata* appears to be the modern species most closely related to the extinct *P.* (*P.*) *staleyi*.

Among Tertiary species, *P.* (*P.*) *staleyi hannibali* (Howe, 1922), known from rocks of Miocene to Pleistocene age in northwestern California and southwestern Oregon, may be a junior synonym of *P.* (*P.*) *staleyi*. Purportedly separate from *P.* (*P.*) *staleyi* by being more quadrate in shape, less inflated, and having bifurcate radial costellae, *P.* (*P.*) *staleyi hannibali* is difficult to identify consistently. As noted by Roth (1979, p. 381), differences between the two taxa "are somewhat analogous to environmental differences between modern populations and individuals of *P. staminea*." Another species related to *P.* (*P*) *staleyi* is *P.* (*P.*) *montesanoensis* (Weaver, 1912), described from the upper Miocene Montesano Formation of Washington. Based on the few published illustrations (Weaver, 1912, 1942; Addicott, 1969, 1976a), *P.* (*P.*) *montesanoensis* evidently is characterized by a somewhat circular outline, subdued radial sculpture and robust concentric growth lamellae.

An Alaskan Tertiary taxon possibly related to *P.* (*P.*) *staleyi* was first cited by Grewingk (1850, p. 278–279, pl. 5, figs. 2a–e) as "*Venerupis petitii* Deshayes var." and was reported to occur on the Alaska Peninsula, Unga Island, and possibly on St. Paul Island. Grewingk's localities include rocks now known to be of Oligocene or Miocene age. His description of a thick-shelled bivalve 38 to 42 mm long and having numerous radial ribs and concentric growth lines, as well as a venerid hinge, may place the taxon in *Protothaca*. However, he illustrated relatively broad radial ribs that are different from those of *P.* (*P.*) *staleyi*. No additional specimens matching Grewingk's (1850) description have been found in Alaska. Based solely on Grewingk's mention of this taxon, Dall (1904, p. 116) proposed the new name *Protothaca grewingkii*.

Protothaca (*Protothaca*) *staleyi* has been reported numerous times in upper Miocene and Pliocene strata from central California to southwestern Oregon. Its oldest verified occurrence is in the Wishkahan faunas of the Empire Formation, southwestern Oregon (Roth, 1979, p. 381), so this species aids in establishing a lower age limit for the Tachilni fauna. Gladenkov (1977) reported *P.* (*P.*) *staleyi* in western Kamchatka only in the Erman Formation, which he refers to the uppermost Miocene.

Protothaca is a common dweller in modern nearshore environments. In the northeastern Pacific, the genus is known in depths from the intertidal zone to 45 m, in sand or gravel, or nestling in crevices (Keen and Coan, 1974).

Type information.—Neotype: ANSP, No. 4490 (Stewart, 1930). Type locality: Mark West Creek, a branch of the Russian River, Sonoma County, northern California; Merced Formation; Pliocene.

Tachilni Formation occurrence.—USGS localities M7140 (1 articulated, closed specimen as "cf.", and 1 valve), M7142 (1 articulated, closed specimen, 1 valve); UA locality A-169 (1 valve).

Figured specimens.—USNM 339778, 339779.

Stratigraphic and geographic range.—The following occurrences are taken from Roth (1979, p. 381–382). Lower upper Miocene (Wishkahan): Empire Formation, Cape Blanco, southwestern Oregon (Roth, 1979). Upper Miocene: Tahana Member of Purisima Formation, northern California (Addicott, 1969); Tinaquaic Sandstone Member of Sisquoc Formation, southern California (Woodring and Bramlette, 1950); Ohlson Ranch Formation, northern California (Peck, 1960); Etchegoin Formation, central California (Adegoke, 1969); Graciosa Coarse-Grained Member and undifferentiated Careaga Sandstone (Woodring and Bramlette, 1950). Pliocene: "Merced (?)" Formation, Santa Clara County, northern Californa (Addicott, 1969).

Family **MACTRIDAE** Lamarck, 1809

Genus **SPISULA** Gray, 1837

Three species of *Spisula* (*Mactromeris*) are recognized in the Tachilni fauna: *S.* (*M.*) *albaria* (Conrad, 1848), *S.* (*M.*) *brevirostrata* Packard, 1916, and *S.* (*M.*) *polynyma* (Stimpson, 1860). The last is by far the most common in Tachilni deposits, followed in order of abundance by *S.* (*M.*) *albaria* and *S.* (*M.*) *brevirostrata*.

Several dozen names are available for North Pacific Cenozoic species of *Spisula* and it is likely that most have no value. The three used for Tachilni specimens are well known in the western American literature and are usually treated as distinct species. However, I attempted to discriminate Tachilni species on the basis of ratios of length to height, and posterior length to total length, and learned that the three shell forms intergrade. This agrees with findings of Moore (1963, p. 83), in reference to *S.* (*M.*) *albaria* of the Miocene Astoria Formation, that the same amount of variation in shell outline may be found in single populations of Holocene species of *Spisula*. The three species in the Tachilni fauna seem to represent end members of an unbroken morphologic series. Determining the degree to which the three morphotypes intergrade, in the Tachilni Formation and elsewhere, would require an effort beyond the scope of this study. Until such a study is done the value of North Pacific species of *Spisula* in making age inferences is extremely limited.

Subgenus **MACTROMERIS** Conrad, 1868

Spisula (Mactromeris) albaria (Conrad, 1848)
Plate 16, figures 5–7

Mactra albaria Conrad, 1848, p. 432, fig. 4; Arnold, 1910, p. 30, pl. 19, fig. 4.
Spisula albaria (Conrad). Dall, 1909, p. 130, pl. 10, fig. 1.
Spisula (*Mactromeris*) *albaria* (Conrad). Moore, 1963, p. 82–83, pl. 28, figs. 1–3, pl. 31, figs. 9, 11; Weaver, 1942, p. 239, pl. 57, figs. 5, 10.

Discussion.—Tachilni specimens assigned to *S.* (*M.*) *albaria* are characterized by their small size, relatively inflated valves, and elevated trigonal outline. Compared to the more numerous specimens of *S.* (*M.*) *polynyma* (Stimpson, 1860), *S.* (*M.*) *albaria* has a more elevated umbo and more narrowly rounded posterior end. Tachilni specimens lack a prominent posterior ridge extending from the umbo to the ventral margin that Moore (1963, p. 83) noted for well-preserved specimens from the Miocene Astoria Formation in Oregon. As Moore (1963) further noted, the variety of shell outlines present in Tertiary *S.* (*M.*) *albaria* may be observed in single collections of Holocene species of *Spisula*.

At least seven subspecies of *S.* (*M.*) *albaria* have been described (Packard, 1916; Weaver, 1942), ranging in age from the middle (?) Oligocene subspecies *S.* (*M.*) *albaria scapoosensis* Clark, 1925, in Oregon, to the Pliocene subspecies *S.* (*M.*) *albaria coosensis* Howe, 1922, in California. The stratigraphic or biogeographic utility of these subspecies is questionable, considering the difficulty in distinguishing the species itself from related forms such as *S.* (*M.*) *polynyma*. Weaver (1942) cited *S. albaria* ranging from late Miocene to Holocene, an interval that is thought to contain *S.* (*M.*) *polynyma* and other species by most workers. There are no undisputed records of *S.* (*M.*) *albaria* from Asia. Zhidkova (1972, p. 140) cited this species, as "cf.", from Miocene and Pliocene strata of Sakhalin and the Kuril Islands, but her figures are of the *S.* (*M.*) *polynyma* morphotype.

Type information.—Holotype: ANSP (missing and presumed lost; Moore, 1963, p. 83). Type locality: Astoria, Oregon; Astoria Formation; middle Miocene.

Tachilni Formation occurrence.—USGS localities M7139 (1 articulated specimen), M7146 (1 valve, as "cf."); UA localities A-169 (1 valve), A-170 (1 valve).

Figured specimen.—USNM 339780.

Stratigraphic and geographic range.—This species is reported to range from the middle or upper Oligocene (Clark, 1925; Addicott, 1973) to Holocene (Weaver, 1942) in the northeastern Pacific, but many literature citations are questionable. The morphotype recognized in the Tachilni fauna is usually cited in Miocene strata of California, Oregon and Washington. Addicott (1976a, p. 105) reported *S.* (*M.*) *albaria arnoldi* (Dall, 1922) restricted to Wishkahan faunas in the Pacific Northwest, but that morphotype is not present in Tachilni collections.

Spisula (Mactromeris) brevirostrata
Packard, 1916
Plate 16, figures 8, 9

Spisula (*Hemimactra*) *brevirostrata* Packard, 1916, p. 296–297, pl. 28, figs. 1a, 1b, 2; Faustman, 1964, p. 124, pl. 1, fig. 8.

Discussion.—Tachilni specimens assigned to *S.* (*M.*) *brevirostrata* are characterized by a relatively elevated shell outline, distinctly concave anterior dorsal margin, and broadly convex posterior dorsal margin, with a broadly rounded posterior end and much more narrowly rounded anterior end. The valves of Tachilni specimens assigned to *S.* (*M.*) *brevirostrata* are not as inflated as those of Tachilni specimens of *S.* (*M.*) *albaria* (Conrad, 1848), or so elongate as those of Tachilni specimens of *S.* (*M.*) *polynyma* (Stimpson, 1860). The *S.* (*M.*) *brevirostrata* morphotype is apparently best developed in adults, because no juveniles with this form occur in the Tachilni fauna or in USGS or UA collections from other formations.

Type information.—Holotype: UCMP 11489. Type locality: UCMP 1875, along east bank of Eel River, one mile north of Scotia, Humboldt County, northwestern California; Wildcat Group; Pliocene or Pleistocene.

Tachilni Formation occurrence.—USGS localities M7146 (1 valve), M7150 (1 valve); UA localities A-170 (1 articulated specimen), A-302 (1 valve).

Figured specimens.—USNM 339781, 339782.

Stratigraphic and geographic range.—The following occurrences are cited by Roth (1979). Middle Miocene (Newportian): Astoria Formation, northwestern Oregon. Lower upper Miocene (Wishkahan): Empire Formation, Coos Bay region, Oregon. Pliocene: "Merced" Formation, Sonoma County, northern California. Pliocene or Pleistocene: Rio Dell Formation and undifferentiated Wildcat Group, northwestern California. Pleistocene: Scotia Bluffs Formation, northwestern California.

Spisula (Mactromeris) polynyma (Stimpson, 1860)
Plate 16, figures 10–12, Plate 17, figures 1, 2

Mactra polynyma Stimpson, 1860, p. 3 [new name for *Mactra ovalis* Gould, 1840, *not* Sowerby, 1817].
Callista voyi Gabb, 1866, p. 24, pl. 5, fig. 41.
Spisula (Hemimactra) voyi (Gabb). Packard, 1916, p. 283–285, pl. 13, fig. 4, pl. 14, figs. 1, 2, pl. 15, figs. 1, 2.
Spisula (Mactromeris) voyi korolevae Zhidkova, 1972, p. 140, pl. 24, figs. 1, 6.

Discussion.—Most Tachilni specimens of *Spisula* belong to this morphotype, which is characterized by large, relatively elongate shells that are only moderately inflated. As with Tachilni specimens of *S. (M.) albaria* (Conrad, 1848) and *S. (M.) brevirostrata* Packard, 1916, most shells of *S. (M.) polynyma* are disarticulated and preserved as molds and casts, and their dentition is not visible.

This species occurs commonly in the North Pacific and northwestern Atlantic oceans (Chamberlin and Stearns, 1963). The name *S. (M.) voyi* (Gabb, 1866) has often been used for Pacific populations, though it has long been recognized that differences from *S. (M.) polynyma* were slight at best (Stewart, 1930; Grant and Gale, 1931). Extensive synonymies for *S. (M.) polynyma* are in Packard (1916), Stewart (1930) and Grant and Gale (1931).

The oldest Alaskan record of this species may be that of Ariey (1978, p. 94), who tentatively recognized it in the lower part of the Yakataga Formation at Yakataga Reef, northeastern Gulf of Alaska, in rocks she assigned a Newportian age. I reexamined her specimen and, due to its poor preservation, can only questionably assign it to *S. (M.) polynyma*. Her evidence for a Newportian age is also not firm, and the specimen may be of Wishkahan age. Shells assignable to *S. (M.) polynyma* are in USGS collections from the middle and upper parts of the Yakataga Formation, but the age of the stratigraphically lowest occurrence is not yet known. This species is also well-known in the Bear Lake Formation on the Alaska Peninsula (Text-fig. 2), which is in part coeval with the Tachilni Formation. The first report of this species in the Tachilni fauna was by Allison (1978, p. 176), based on some of the present specimens, and no verified older occurrences in Alaska are known. A possible ancestor of *S. (M.) polynyma* is *S. (M.) equilateralis* (Clark, 1932), a similar species that occurs in upper Oligocene or lower Miocene strata of the upper Poul Creek Formation in the Cape Yakataga area.

The oldest reliable northwestern Pacific record of *S. (M.) polynyma* is that of Slodkewitsch (1938a, p. 485–490) from the "upper horizon of the Kavran" Group of western Kamchatka. In modern terms (Menner, Baranova, and Zhidkova, 1977) this stratigraphic interval is equivalent to the Etolon Formation of late Miocene age. Slodkewitsch (1938a) also cited this species from the "upper horizon of the Tighil (?)" Group of western Kamchatka, but those rocks are of Eocene age, so this record is likely based on a mistaken identification or stratigraphic assignment. Zhidkova *et al.* (1968, p. 125) report this species in upper Miocene or Pliocene rocks of Sakhalin, and Zhidkova (1972, p. 139–140) cited it in the lower Pliocene Okruglovska Formation and the middle or upper Pliocene Okeanska Formation of Paramushir Island, Kuril Islands. From the former formation Zhidkova (1972, p. 140) named a new subspecies, *S. (M.) voyi korolevae*, which is synonymized here with *S. (M.) polynyma*. Records in Japanese Tertiary faunas are in need of review. This species has been cited in strata as old as the Eocene or Oligocene Poronai Formation (Takeda, 1953) and is frequently named in Miocene and Pliocene faunas (Hatai and Nisiyama, 1952; Masuda and Noda, 1976).

Type information.—Holotype: location and type locality unknown.

Tachilni Formation occurrence.—USGS localities M4044 (1 articulated specimen), M5169 (1 valve), M7146 (abundant valves), M7150 (abundant valves), M7256 (5 valves), M7258 (1 valve); UA localities A-169 (abundant valves), A-302 (abundant valves).

Figured specimens.—USNM 339783, 339784, 339785, 339786, 339787.

Stratigraphic and geographic range.—Because of the profound taxonomic complexities surrounding the *S. (M.) polynyma* morphotype it is not now possible to cite its first appearance or give its biogeographic history. The species evidently had a North Pacific origin (Durham and MacNeil, 1967) and is widely reported in Miocene through Pleistocene faunas from northeastern Honshu to northwestern California. The

modern southern end-point of its range in Asia is variously cited as northern Sakhalin (Chamberlin and Stearns, 1963) or Fukushima Prefecture, northeastern Honshu (Kamada, 1962, p. 125). As documented by Chamberlin and Stearns (1963), the range in the northeastern Pacific and Arctic Oceans is from Point Barrow, northwestern Alaska, to the Straits of Juan de Fuca, Washington. In the northwestern Atlantic the range is from northern Newfoundland south to off of Long Island, New York. The species is absent from the intervening Arctic Ocean coast. For northwestern Atlantic populations Chamberlin and Stearns (1963) observed that limiting temperatures for survival and reproduction are 5.5°C and 13°C, and further noted living specimens in depths from the intertidal zone to 80 m.

Family **TELLINIDAE** Blainville, 1814

Genus **PERONIDIA** Dall, 1900

Peronidia aff. **P. lutea alternidentata**
(Broderip and Sowerby, 1829)
Plate 17, figures 3–9, Plate 18, figures 1–3

Discussion.—This taxon is characterized by a large, elongate, inflated, and relatively heavy shell that is rounded anteriorly and truncated posteriorly. The anterior end is distinctly longer than the posterior, and the only sculpture is of low, irregularly spaced, concentric growth lines.

The Tachilni taxon belongs to a group of late Cenozoic tellinids closely related to the well-known North Pacific Pleistocene and Holocene subspecies *Peronidia lutea alternidentata* (Broderip and Sowerby, 1829). However, the two taxa differ in shell proportions, size, and pallial line configuration. Shells of *P. lutea alternidentata* are equilateral to slightly longer posteriorly (Coan, 1971, p. 9), whereas all Tachilni specimens are longer anteriorly, and the difference in gross appearance between the two taxa is distinctive. The largest Tachilni specimen is 79.1 mm long, compared to 110 mm for the largest specimen of *P. lutea alternidentata* cited by Coan (1971, p. 9). Internal molds of some Tachilni specimens preserve pallial lines and adductor muscle scars. Compared to the pallial sinus of *P. lutea alternidentata* (figured in Coan, 1971, fig. 1), the left-valve sinus of the Tachilni taxon is more spacious and has a much blunter anterior termination (Pl. 17, figs. 5, 9), and the right-valve sinus is more highly arched dorsally (Pl. 17, fig. 6).

Two Japanese tellinids are very similar to the Tachilni taxon: the Miocene species *P. protovenulosa* (Nomura, 1935a) and the Pliocene or Pleistocene to Holocene species *P. zyonoensis* (Hatai and Nisiyama, 1939). *Peronidia protovenulosa* differs from the Tachilni taxon by being more elongate and having a more sharply angular posterior end. Nomura (1935a, p. 87) cited an average length to height ratio of 1.83 for four specimens of *P. protovenulosa*. This same ratio for six Tachilni specimens is 1.61, and a juvenile seventh specimen has a ratio of 1.82. These few measurements suggest that Tachilni adults differ in shell proportions from adult *P. protovenulosa*. *Peronidia zyonoensis* occupies a middle position between *P. protovenulosa* and the Tachilni taxon. Ogasawara (1977, p. 124) noted an average length to height ratio of 1.72 for 18 specimens of *P. zyonoensis* from the Pliocene or Pleistocene Omma Formation of central Honshu. Thus, *P. zyonoensis* evidently is more elongate than the Tachilni taxon, and also has a sharper posterior end and a distinctly more flattened posterior dorsal margin. The average length to height ratio of six specimens of *P. lutea alternidentata* from the Chukchi Sea (UA collection) is 1.65, about the same as that of the Tachilni taxon and close to that of *P. zyonoensis*. Coan (1971, p. 8) considered *P. zyonoensis* a junior synonym of *P. lutea alternidentata*.

More than half of the Tachilni specimens have closed, articulated valves, a condition that suggests little or no post-mortem transport.

Tachilni Formation occurrence.—USGS localities M310 (1 valve, as "?"), M7139 (2 articulated, closed adults), M7142 (1 articulated, closed adult, and 1 valve), M7146 (1 articulated, closed adult), M7149 (1 valve), M7150 (abundant valves); UA localities A-169 (1 valve), A-170 (3 articulated, closed adults); CAS locality 60278 (1 valve).

Figured specimens.—USNM 339788, 339789; UA 2477, 2478.

Stratigraphic and geographic occurrence.—The Tachilni taxon belongs to a complex of northwestern Pacific tellinids that occur in Miocene and younger strata in Japan, Sakhalin and Kamchatka, and has modern representatives from southern Japan to Arctic Alaska.

Genus **MACOMA** Leach *in* Ross, 1819

Subgenus **MACOMA** Leach *in* Ross, 1819

Macoma (Macoma) cf. **M. (M.) astori** Dall, 1909
Plate 18, figures 4–18

Macoma astori Dall, 1909, p. 128, pl. 14, figs. 1, 11; Weaver, 1942, pt. 1, p. 213, pt. 3, pl. 49, fig. 14; Moore, 1963, p. 81, pl. 28, fig. 15 [as "cf."], pl. 29, fig. 12 [refigured holotype]; Addicott, 1976a, p. 107, pl. 2, fig. 14.

Discussion.—This shell is slightly elongate and

ranges in outline from ovate to somewhat trigonal. The umbones are prominent and located about three-fifths of the distance from the anterior to posterior extremity. The anterior dorsal margin is slightly convex and merges smoothly with the evenly rounded anterior margin. The ventral margin is evenly rounded except for a very slight flattening or convexity along its middle to posterior portion. The posterior dorsal margin is straight to slightly convex and joins, with varied degrees of abruptness, a subtruncate to narrowly rounded posterior extremity. The valves are moderately inflated and have a weak flexure to the right posteriorly. A shallow groove just below the dorsal margin extends from the umbo to the posterior extremity of most specimens, but is obsolete on some individuals. Sculpture consists only of fine concentric growth lines. Interior features are not visible. The largest Tachilni specimen is 45.8 mm long and several other adults are nearly that size.

The difficulties inherent in identifying species of *Macoma* are especially apparent in these Tachilni specimens. As noted by Coan (1971, p. 24), *M.* (*M.*) *astori* seems closely related to *M.* (*M.*) *brota* Dall, 1916. The latter species, in turn, is difficult to distinguish from *M.* (*M.*) *lipara* Dall, 1916, and the two have been considered synonymous (Bernard, 1967). In addition, *M.* (*M.*) *brota* may be so similar to some specimens of *M.* (*M.*) *calcarea* (Gmelin, 1791), that hybridization between the two has been suspected (Dunnill and Coan, 1968, p. 17).

Tachilni specimens are only tentatively assigned to *M.* (*M.*) *astori* because that species is known from relatively few specimens, and because its range of morphologic variation is imperfectly understood. Most Tachilni shells have outlines similar to those of the type specimens of *M.* (*M.*) *astori* figured by Dall (1909), but many are relatively higher and are identical in outline to a specimen figured by Moore (1963, pl. 28, fig. 15) as *M.* cf. *M. astori*. The most variable features of the Tachilni shells are their relative height, the degree to which the groove below the posterior dorsal margin is developed, and the degree of bluntness of the posterior termination.

This taxon seems to be absent from Asiatic faunas. A specimen cited as *M. astori* and reported from unnamed Miocene beds in eastern Kamchatka by Slodkewitsch (1938b, p. 172, pl. 93, fig. 7) appears too poorly preserved to identify below the generic level.

Seven of 28 Tachilni specimens are articulated and all but one of the former have closed valves.

Type information.—Holotype: USNM 153937. Type locality: Coos Bay, southwestern Oregon; Empire Formation; upper Miocene.

Tachilni Formation occurrence.—USGS localities M7140 (7 articulated, closed specimens, 15 valves), M7142 (2 articulated, closed specimens, 4 valves), M7150 (1 articulated, closed specimen, 4 valves), M7203 (2 valves); UA locality A-170 (1 articulated, closed specimen, 3 valves).

Figured specimens.—USNM 339790–339800.

Stratigraphic and geographic range.—*Macoma* (*Macoma*) *astori* has been reported only in Newportian and Wishkahan faunas of Oregon. Upper lower to middle Miocene (Newportian): Astoria Formation, northwestern Oregon (Moore, 1963; Addicott, 1976a). Lower upper Miocene (Wishkahan): Empire Formation, Coos Bay, southwestern Oregon (Dall, 1909; Weaver, 1942; Addicott, 1976a).

Macoma (Macoma) optiva (Yokoyama, 1923)
Plate 19, figures 1–10

Tellina optiva Yokoyama, 1923, p. 6, pl. 2, figs. 3a, 3b, 4.

Macoma optiva (Yokoyama). Nomura, 1935b, p. 36, pl. 4, figs. 4, 12; Slodkewitsch, 1938b, p. 172, pl. 94, figs. 4–9; Kanno, 1960, p. 299–300, pl. 43, figs. 10a–10c, pl. 44, figs. 1, 2; Kamada, 1962, p. 128–130, pl. 15, figs. 1–6; Ilyina, 1963, p. 81–82, pl. 27, figs. 6, 7.

Macoma n. sp.? Moore, 1963, p. 81, pl. 29, figs. 10–11; Addicott, 1976b, p. 33, pl. 8, fig. 4.

Discussion.—This species is characterized by its relatively large size and height, semicircular anterior outline, and sharply sloping posterior dorsal and ventral margins that join a narrow, subtruncate posterior end. The umbo is nearly central, but slightly closer to the anterior end. The valves are moderately inflated, moderately to strongly flexed to the right posteriorly, and sculptured only with fine concentric growth lines. The pallial sinus of Tachilni specimens agrees well in shape with that of a syntype specimen figured by Yokoyama (1923, pl. 2, fig. 3b).

This extinct Tertiary species is most closely related in form to *M.* (*M.*) *obliqua* (Sowerby, 1817), a Pleistocene to Holocene species of the northeastern Pacific and Arctic Oceans (Coan, 1971). However, *M.* (*M.*) *optiva* differs by being much larger (to 76.4 mm length herein, versus to 50 mm length for *M.* (*M.*) *obliqua*), by being slightly elongate posteriorly rather than being equidimensional or slightly elongate anteriorly, by having more sharply sloping posterior dorsal and ventral margins, by having a subtruncate rather than rounded posterior termination, and by having a posterior end usually more strongly flexed to the right.

Macoma (*Macoma*) *optiva* has been widely reported in middle and upper Tertiary faunas of northern Japan and the far-eastern U.S.S.R. (Slodkewitsch, 1938a; Hatai and Nisiyama, 1952; Ilyina, 1963; Ma-

suda and Noda, 1976). The only previous citation of this species in North America was that of Allison and Marincovich (1981), who tentatively assigned to this species a juvenile specimen from upper Oligocene or lowermost Miocene beds of the Narrow Cape Formation of Sitkinak Island in the western Gulf of Alaska. That specimen still cannot be confidently assigned to *M.* (*M.*) *optiva,* so Tachilni specimens are the first verified occurrence of this species in the northeastern Pacific. However, Moore (1963) was the first to note an evidently undescribed species of *Macoma* in Miocene beds of Oregon, and Addicott (1976a, p. 101) thought this species was restricted to his newly proposed Pillarian Stage (lower Miocene) of Washington and Oregon.

Macoma (*Macoma*) *optiva* was described from upper Miocene beds of the Fujina Formation, then thought to be of Pliocene age, in southwestern Honshu (Yokoyama, 1923; Nomura and Hatai, 1939). All Japanese reports since then have been of Miocene occurrences (Hatai and Nisiyama, 1952; Masuda and Noda, 1976). The oldest record of this species in Japan or elsewhere is from the Chichibu Basin of central Honshu, where *M.* (*M.*) *optiva* is reported in lower Miocene rocks of the Nenokami Sandstone and the Ushikubitoge Formation (Yokoyama, 1925; Kanno, 1960). This species is no longer thought to occur in Pliocene faunas, and the youngest Japanese occurrences are in beds assigned a late Miocene age (Masuda and Noda, 1976).

Macoma (*Macoma*) *optiva* has been widely reported in Miocene faunas of western and eastern Kamchatka (Slodkewitsch, 1938a, p. 472; 1938b, p. 172; Ilyina, 1963, p. 81–82), Sakhalin (Ilyina, 1954, p. 231; Ilyina, 1963, p. 82), and the Kuril Islands (Zhidkova, 1972, p. 138). Some of these occurrences originally were thought to be of Pliocene age, but evidently all are now considered to come from Miocene faunas (Menner, Baranova, and Zhidkova, 1977; Gladenkov, 1977). Gladenkov (1977) noted this species present only in the Kakert and Etolon Formations of Kamchatka, to which he assigned middle Miocene ages. Menner, Baranova, and Zhidkova (1977) considered the same strata to span an age of about early middle to early late Miocene. There seem to be no reports of *M.* (*M.*) *optiva* in early Miocene faunas of the far-eastern U.S.S.R., which may be the result of incomplete collecting in that region, because the species is known in strata of that age in Japan (Kanno, 1960), Oregon and Washington (Addicott, 1976a, 1976b), and possibly Alaska (Allison and Marincovich, 1981).

Based on Kanno's (1960, p. 152–153, 155–156) observations of lower Miocene faunas in the Chichibu Basin [formerly thought to be of Oligocene age; S. Kanno, oral commun., 1981], this species had a rather broad bathymetric range. In those faunas, *M.* (*M.*) *optiva* occurs in inferred shallow-water assemblages (0–200 m) of the Nenokami Sandstone and the Shirasu Sandstone Member of the Ushikubitoge Formation, as well as in inferred deeper-water assemblages (more than 200 m) of the Tomita Siltstone Member of the Ushikubitoge Formation. The Nenokami and Shirasu faunas were inferred to represent warm to temperate marine hydroclimates, and the Tomita fauna to represent a temperate to cold hydroclimate.

Type information.—Type specimens [syntypes?]: GT, not numbered (Hatai and Nisiyama, 1952). Type locality: "lake cliff about 300 m NWW [?] of Jyakusan, N of Fujina," Shimane Prefecture, southwestern Honshu, Japan (Hatai and Nisiyama, 1952); Fujina Formation; upper Miocene.

Tachilni Formation occurrence.—USGS localities M7150 (1 valve), M7256 (4 valves); UA localities A-169 (2 articulated, closed specimens), A-170 (5 articulated, closed specimens), A-302 (1 valve, as "?"); CAS localities 60278 (1 articulated, closed specimen), 60279 (9 articulated, closed specimens, 1 valve), 60280 (1 valve).

Figured specimens.—UA 2479–2483.

Stratigraphic and geographic range.—Known mainly in Asian faunas, this species ranges from upper Oligocene or lowermost Miocene to upper Miocene. Upper Oligocene or lowermost Miocene: Narrow Cape Formation of Sitkinak Island, Trinity Islands, western Gulf of Alaska (Allison and Marincovich, 1981, as "cf."). Lower Miocene: Tomita Siltstone Member and Shirasu Sandstone Member of Ushikubitoge Formation, and Nenokami Sandstone, Chichibu Basin, central Honshu, Japan (Kanno, 1960). Lower Miocene (Pillarian): Nye Mudstone, northwestern Oregon (Addicott, 1976a); Clallam Formation, northwestern Washington (Addicott, 1976b). Upper lower or middle Miocene (Newportian): Astoria Formation, northwestern Oregon and southwestern Washington (Moore, 1963; Addicott, 1976a, 1976b). Lower or middle Miocene: Honya Formation, Joban coal field, central Honshu, Japan (Kamada, 1962); Kuluven Formation of Vayampol Group and Ilyinsk Formation of Kavran Group, western Kamchatka (Slodkewitsch, 1938a, 1938b; Ilyina, 1963). Middle Miocene: Kakert Formation of Kavran Group, western Kamchatka, and Kurasai Formation and lower part of Maruyama Formation, south Sakhalin (Ilyina, 1963). Middle (?) Miocene: Numanouchi, Kokozura and Nakayama Formations, Joban coal field, central Honshu (Kamada, 1962). Middle or upper Miocene: Okobykayska For-

mation of north Sakhalin (Zhidkova, 1972). Upper Miocene: Fujina Formation, Shimane Prefecture, southwestern Honshu (Yokoyama, 1923; Nomura and Hatai, 1939). Miocene, exact age unknown: Sankubetsu (Kanno, 1960), Kawabata and Tokomuro (Masuda and Noda, 1976), and Wakkanai (Hatai and Nisiyama, 1952) Formations of Hokkaido; Kadonosawa, Ainaigawa, Sunakose, and [?] Takahoko Formations of northern Honshu (Kanno, 1960; Masuda and Noda, 1976); Nagano, Itsukaichi, Okazaki, Ohno, and Yamanouchi Formations of central Honshu (Masuda and Noda, 1976); Kaisekizan and Muro Formations of southern Honshu (Masuda and Noda, 1976); unnamed sandstone, Korf Gulf, eastern Kamchatka, and unnamed beds along Kavran, Tnonkhlno, Lanych and Etolon Rivers, western Kamchatka (Slodkewitsch, 1938a, 1938b); Rykhlaya Group (Slodkewitsch, 1938a, 1938b) and Sertunai, Alexandrovska and Borska Formations (Zhidkova, 1972) of Sakhalin; Alekhinska Formation, Kunashir Island, Kamuyska Formation, Iturup Island, and Shumnovska Formation, Paramushir Island, Kuril Islands, U.S.S.R. (Zhidkova, 1972).

Macoma incongrua (von Martens, 1865)
Plate 18, figure 19

Tellina incongrua von Martens, 1865, p. 430–431.
Macoma incongrua (von Martens). Kanno, 1971, p. 77–78, pl. 6, fig. 6, pl. 9, figs. 9, 10, 12; Addicott *et al.*, 1971, p. C20, figs. 5n, 5o [as "cf."]; Marincovich, 1980, p. C9, fig. 10; Allison and Marincovich, 1981, table 6, pl. 1, fig. 26.

Discussion.—This well-known Alaskan Tertiary species has valves that are inflated anteriorly and have a broadly rounded anterior end. The posterior dorsal and ventral margins slope steeply and join an acutely angled posterior termination. There is a distinct flexure to the right posteriorly.

Macoma incongrua is represented in Tachilni collections by only three specimens, only one of which is well preserved. It differs from juveniles of *M.* (*M.*) *optiva* (Yokoyama, 1923) by its straight, not convex, anterior dorsal margin that joins the anterior margin at an angle rather than blending smoothly with it. In addition, *M. incongrua* has a narrowly rounded posterior extremity, compared to the subtruncate posterior end of *M.* (*M.*) *optiva*.

Even though *M. incongrua* is the most common Tertiary species of *Macoma* Leach *in* Ross, 1819 in the eastern Gulf of Alaska (Kanno, 1971; Marincovich, 1980), it is rare in the western Gulf—the Alaska Peninsula and adjacent islands. The only previous report of *M. incongrua* in the western Gulf of Alaska is in upper Oligocene or lowermost Miocene rocks of the Narrow Cape Formation of Sitkinak Island (Allison, 1978; Allison and Marincovich, 1981). In Japan, this species is reported in Neogene faunas of central and northern Honshu and Hokkaido (Hatai and Nisiyama, 1952; Masuda and Noda, 1976). There seem to be no reported finds in the far-eastern U.S.S.R. Reports of *M. incongrua* in Pleistocene faunas of Oregon and Washington have been referred to *M.* (*M.*) *obliqua* (Sowerby, 1817) by Coan (1971) and Kennedy (1978).

The modern occurrence of *M. incongrua* in the western Pacific is reported to be in muddy bottoms ranging in depth from the intertidal zone to 10 m (Kanno, 1971).

Type information.—Lectotype (designated by Coan, 1971, p. 26): ZMH, No. 7624. Type locality: Yokohama, Japan; Holocene.

Tachilni Formation occurrence.—USGS localities M7142 (1 valve, as "cf."), M7146 (1 valve), M7150 (1 valve, as "cf.").

Figured specimen.—USNM 339801.

Stratigraphic and geographic range.—The known range of this species is from the upper Oligocene or lowermost Miocene to Holocene. Upper Oligocene or lowermost Miocene (Juanian): Narrow Cape Formation of Sitkinak Island, western Gulf of Alaska (Allison, 1978; Allison and Marincovich, 1981). Upper Oligocene or lower Miocene: upper part of Poul Creek Formation, Yakataga district, eastern Gulf of Alaska (Kanno, 1971). Upper lower to middle Miocene (Newportian): Topsy Formation, Lituya district, eastern Gulf of Alaska (Marincovich, 1980); Yakataga Formation, Yakataga district, eastern Gulf of Alaska (USGS coll.). Middle (?) Miocene: Chiganoura Formation, Miyagi Prefecture, northeastern Honshu, Japan (Nomura, 1935b). Middle or upper Miocene: Yakataga Formation, Yakataga and Lituya districts, eastern Gulf of Alaska (Ariey, 1978; USGS coll.). Upper (?) Miocene: Takinoue Formation, Hokkaido, Japan (Kanno and Ogawa, 1964). Miocene, exact age unknown: Kamiyokoze Formation, Saitama Prefecture, central Honshu (Watanabe, Arai, and Hayashi, 1950), and Kubota Formation, Fukushima Prefecture, northern Honshu (Iwasaki, 1970), Japan. Pliocene: Chinkope Formation, Hokkaido (Sawada, 1962). Holocene: Kyushu north to Hokkaido, Japan, the Kuril Islands, Korea, and China (Kuroda, Habe, and Oyama, 1971).

Family **SOLENIDAE** Lamarck, 1809

Genus **SILIQUA** Megerle von Muehlfeld, 1811

Siliqua cf. **S. alta** (Broderip and Sowerby, 1829)
Plate 19, figures 11–13, Plate 20, figure 1

Solen altus Broderip and Sowerby, 1829, p. 362.
Siliqua patula alta (Broderip and Sowerby). Oldroyd, 1924, vol. 1, p. 190, pl. 47, figs. 1, 2.
Siliqua alta (Broderip and Sowerby). Grant and Gale, 1931, p. 388–389, pl. 21, fig. 1.

Discussion.—Compared to similar northeastern Pacific species of *Siliqua*, this species is characterized by a relatively short shell, broadly rounded posterior end, and relatively elevated posterior dorsal margin or flange, with its greatest height posterior to the beaks (Roth, 1979, p. 335). *Siliqua alta* is characterized by a vertical internal rib (Roth, 1979), whereas Tachilni specimens have ribs with a slight anterior slant. Combined with the preservation of Tachilni specimens only as internal molds, the variation in rib inclination makes identification as *S. alta* somewhat tentative.

The first appearance of *Siliqua* in the Pacific Northwest was in Wishkahan faunas (Addicott, 1976a, p. 98). Approximately coeval occurrences are reported in California (Roth, 1979, p. 330) in the upper Miocene Sisquoc Formation (Woodring and Bramlette, 1950) and Santa Margarita Formation (Adegoke, 1969), as well as in the upper Miocene San Pablo Group (Weaver, 1949; Hall, 1958). The "*Siliqua* sp." reported by Kanno (1971) from the highest exposed bed of the Yakataga Formation at Yakataka Reef, northeastern Gulf of Alaska, is of Wishkahan or younger age. The earliest reported occurrence of *S. alta* is in Pliocene strata of the Rio Dell Formation and undifferentiated Wildcat Group of northwestern California (Roth, 1979, p. 334). *Siliqua lucida* (Conrad, 1837) has been reported in several upper Miocene formations in California (Roth, 1979, p. 339), as well as in the Wishkahan Skonun Formation of British Columbia (Addicott, 1978, p. 680). However, Tachilni specimens of *Siliqua* appear to differ from *S. lucida* by having an anteriorly inclined rather than vertical internal rib, and by lacking a groove to set off the posterior dorsal margin or flange.

Modern species of *Siliqua* are reported to live in depths from the intertidal zone to 60 m, burrowed into sandy or silty substrates (Kanno, 1971, p. 74).

Type information.—Holotype: presumably in BM(NH). Type locality: Arctic Ocean; Holocene.

Tachilni Formation occurrence.—USGS localities M310 (2 valves), M5168 (1 articulated, open specimen), M7146 (2 articulated, closed specimens, 2 valves), M7150 (4 articulated, closed specimens; 4 articulated, open specimens; 16 valves), M7256 (1 valve); UA locality A-301 (1 valve).

Figured specimens.—USNM 339802, 339803, 339804; UA 2484.

Stratigraphic and geographic range.—The stratigraphic range of *S. alta* is difficult to assess from the literature because of disagreement on the morphologic limits assigned by authors to *Siliqua* species. Although Roth (1979) reported the first *S. alta* in Pliocene strata of northwestern California, he noted the presence of a form like *S. alta* in Neogene rocks of central and southern California, including the upper Miocene Sisquoc Formation and Cebada and Graciosa Members of the Careaga Sandstone near Santa Maria (Woodring and Bramlette, 1950), the upper Miocene Etchegoin Formation of the San Joaquin Valley (Grant and Gale, 1931; Woodring, Stewart, and Richards, 1940), and the upper Miocene Pancho Rico Formation of the Salinas Valley (Durham and Addicott, 1965). Roth (1979) noted the following occurrences: Pliocene: Rio Dell Formation and undifferentiated Wildcat Group, northwestern California. Lower Pleistocene: type Merced Formation near San Francisco, California (Glen, 1959); unnamed beds at Moonstone Beach, northwestern California. Upper Pleistocene: Scotia Bluffs Formation, northwestern California. Pleistocene: Gubik Formation near Nome, Alaska (MacNeil, Mertie, and Pilsbry, 1943). Holocene: Chukchi and Bering Seas to Cook Inlet, Alaska, and northern Honshu, Japan (Habe, 1965), in depths of zero to 55 m (Roth, 1979).

Family **MYIDAE** Lamarck, 1809

Genus **MYA** Linnaeus, 1758

Subgenus **MYA** Linnaeus, 1758

Mya (Mya) truncata Linnaeus, 1758

Plate 20, figures 2–7

Mya truncata Linnaeus, 1758, p. 670.

Mya (Mya) truncata Linnaeus. Grant and Gale, 1931, p. 414–415 [contains extensive synonymy]; MacNeil, 1965, p. G38–G40, pl. 8, figs. 1–12, pl. 9, figs. 1–3, 5–20 [contains extensive synonymy].

Mya truncata Linnaeus. Nagao and Inoue, 1941, p. 155–156, pl. 33, figs. 5, 9, 10 [contains extensive synonymy]; Fujie, 1957a, p. 399–400, pl. 3, figs. 1–4.

Discussion.—Tachilni specimens are typical of this species and have ovate shells that terminate in sharply truncate and widely gaping posterior ends with flared margins. The umbo is moderately elevated, and anterior end broadly rounded, and sculpture consists only of irregular, coarse growth lines. The pallial line and dentition are not observable on Tachilni specimens. The largest Tachilni specimen is 77.0 mm long and 59.1 mm high, and most other adults are close to this in size. Two juvenile specimens are questionably assigned to this species because their posterior truncations are poorly expressed (one is shown on Pl. 20, fig. 7).

This is the most ubiquitous Alaskan Cenozoic species of *Mya* and occurs in several formations of Miocene and younger age. It has been reported previously in the Tachilni Formation (Marincovich *in* McLean, Englehardt, and Howell, 1978), and occurs in USGS collections from the Bear Lake Formation. In the eastern

Gulf of Alaska, *M.* (*M.*) *truncata* is known from numerous localities in the Yakataga Formation (Clark, 1932; MacNeil, 1965; Kanno, 1971) that range in age from Wishkahan (?) to Pleistocene, based on USGS collections. In the northwestern Pacific the species has been reported in Miocene and Pliocene strata of Hokkaido (Nagao and Inoue, 1941; Fujie, 1957b), western Kamchatka, and northern Sakhalin (Slodkewitsch, 1938a, 1938b). As MacNeil (1965, p. G39) noted, *M.* (*M.*) *truncata* is known from many geographic localities and stratigraphic horizons in the North Pacific, Arctic and North Atlantic Oceans.

The age of the first appearance of *M.* (*M.*) *truncata* is uncertain. MacNeil (1965, p. G39) considered the earliest occurrence to be in the lower part of the Yakataga Formation of the eastern Gulf of Alaska, and in the Chikubetsu Formation of Hokkaido, which he thought to be of early middle Miocene age. Strauch (1972) evidently thought the earliest representatives to be of late Miocene age from the northwestern Pacific. USGS collections show this species present in the earliest Wishkahan faunas of the Yakataga Formation at Cape Yakataga, but absent from the underlying Newportian fauna. The first appearance of *Mya* in the Pacific Northwest is also in Wishkahan faunas (Addicott, 1976a). The possibility that *M.* (*M.*) *truncata* occurs only in Wishkahan and younger faunas needs to be tested by further collecting.

Nearly all Tachilni specimens of *M.* (*M.*) *truncata* are articulated and closed, and I collected some in life positions. This suggests that Tachilni sediments have lain undisturbed since deposition. The commonly accepted bathymetric range for modern species of *Mya* is 0–50 m (Keen and Coan, 1974), though Bernard (1979b) claims depths to "100 m or more."

Type information.—Holotype: in collections of the LSL (Dodge, 1952, p. 28). Type locality: "in European seas"; Holocene.

Tachilni Formation occurrence.—USGS localities M310 (1 valve, as "cf."), M4044 (1 articulated, closed adult), M5166 (2 articulated, closed adults), M5169 (1 articulated, closed adult, 2 valves), M7142 (2 articulated, closed adults), M7143 (3 articulated, closed adults, and 1 valve), M7146 (2 articulated, closed adults, and 2 valves), M7149 (1 articulated, closed adult), M7150 (1 articulated, closed adult, 4 valves), M7256 (8 valves); UA localities A-170 (1 articulated, closed adult), A-301 (5 juvenile valves, as "?").

Figured specimens.—USNM 339805, 339806; UA 2485, 2486.

Stratigraphic and geographic range.—This ubiquitous species ranges from the middle or upper Miocene to Holocene. Many stratigraphic occurrences are cited in the American, Japanese and Russian literature, and those given below are only the more relevant ones. Middle or upper Miocene: Honbetsu and Chikubetsu Formations, Hokkaido, Japan (Fujie, 1957a); Bear Lake Formation, Alaska Peninsula, Alaska (USGS coll.); Vayampol and Kavran Groups, western Kamchatka (Slodkewitsch, 1938a, 1938b). Upper middle (?) Miocene (Newportian): lower part of Yakataga Formation, Cape Yakataga, eastern Gulf of Alaska (MacNeil, 1965; USGS coll.). Lower upper Miocene (Wishkahan): Tachilni Formation, Cape Tachilni, Alaska Peninsula (Marincovich *in* McLean, Englehardt, and Howell, 1978); Empire Formation, Coos Bay, Oregon (Dall, 1909). Lower Pliocene: southernmost occurrence in Towsley Formation, Ventura County, southern California (MacNeil, 1965; Kern, 1973). Upper Pliocene: southernmost occurrence in Pico Formation, Ventura County, southern California (MacNeil, 1965). Undifferentiated Pliocene: Pomyr Group, Schmidt Peninsula, northern Sakhalin (Slodkewitsch, 1938a, 1938b). Lower Pleistocene: southernmost eastern Pacific report in Timms Point Silt Member of San Pedro Formation, San Pedro, southern California (Clark, 1931). Upper Pleistocene: numerous literature citations in circumarctic and circumboreal regions, but the southernmost occurrence is unknown to me. Holocene: circumarctic and circumboreal; in the Atlantic, south to the Bay of Biscay and the Mediterranean, and Cape Cod; in the eastern Pacific, south to at least Puget Sound, Washington, possibly to northern California; in the western Pacific, south to Rikuchu, Iwate Prefecture, northeastern Honshu (Bernard, 1979b).

Subgenus **ARENOMYA** Winckworth, 1930

Mya (Arenomya) elegans (Eichwald, 1871)

Plate 20, figures 8, 9, Plate 21, figures 1–3

Mya crassa Grewingk, 1850, p. 282–283 [not p. 355, as stated by previous workers], pl. 6, figs. 2a–2d; Eichwald, 1871, p. 124.

not *Mya crassa* Vallot, 1801, p. 7.

not *Mya crassa* Wood, 1815, p. 106, pls. 20–21.

Anatina elegans Eichwald, 1871, p. 119–121 [new name for "*Mya arenaria* Linnaeus" of Grewingk, 1850, p. 283–284, pl. 6, figs. 3a–3c [=*Mya crassa* Grewingk, 1850].

Mya intermedia Dall, 1898, p. 857; Dall, 1921, p. 52, pl. 4 [not *Mya intermedia* Sowerby, 1814, p. 173].

Mya (*Mya*) *arenaria profundior* Grant and Gale, 1931, p. 414 [new name for *Mya crassa* Grewingk, 1850].

Mya (?*Arenomya*) *elegans* (Eichwald). MacNeil, 1965, p. G29–G30, pl. 2, figs. 3–4, 6–8, pl. 3, figs. 1, 4 [contains extensive synonymy].

Mya (*Arenomya*) *elegans* (Eichwald). Bernard, 1979b, p. 199–200, figs. 19–21.

Discussion.—Tachilni specimens of *M.* (*A.*) *elegans* have an elongate trigonal shell with a broadly rounded

anterior end and narrowly rounded posterior end. The umbo is moderately to strongly elevated, so that some specimens have their height nearly equal to their length. The posterior gape is small. Sculpture consists only of relatively coarse concentric growth lines. As seen on some internal molds of articulated specimens, the chondrophore is large, alate, and has a relatively shallow ligamental pit and a large anterior buttress that forms a triangular platform. The pallial sinus opens broadly and extends about two-thirds of the distance from the posterior to anterior adductor muscle. Tachilni specimens are about 80 mm long and 60 mm high, with the largest specimen 101.0 mm long and 77.5 mm high (Pl. 21, figs. 1–3).

Specimens of *M.* (*A.*) *elegans* similar in form to Tachilni shells occur in Miocene faunas of the type Narrow Cape Formation on Kodiak Island, and the Bear Lake Formation at several localities on the Alaska Peninsula. The largest known collection of Tertiary specimens of *M.* (*A.*) *elegans* comes from the Yellow Bluff Creek section of the Bear Lake Formation (USGS coll.), near Black Peak on the Alaska Peninsula (Text-fig. 2). Most specimens from the Yellow Bluff Creek beds, of probable middle or late Miocene age, are identical to Tachilni shells, but several are relatively more elongate and have less elevated umbones, as in the Yellow Bluff Creek specimen designated as the neotype of *M. crassa* by MacNeil (1965, pl. 2, fig. 3). Most specimens of *M.* (*A.*) *elegans* from the type Narrow Cape Formation on Kodiak Island are similar to the neotype of *M. crassa,* although some have a more steeply sloping posterior dorsal margin and consequently more sharply pointed posterior termination.

Modern specimens assigned to *M.* (*A.*) *elegans* differ from Tertiary specimens by being larger (to 180 mm long; Bernard, 1979b) and by having a relatively more elongate shell with a less elevated umbo, a relatively more elongate posterior end, a posterior termination that is expanded and broadly rounded, a deeper pallial sinus, and a much wider posterior gape. It is possible that Holocene specimens are at least subspecifically distinct from Tertiary specimens. An extensive study of large populations, beyond the scope of the present study, is needed to test this idea. Alaskan Pleistocene specimens of *M.* (*A.*) *elegans,* not numerous in collections, seem to have the morphology of modern individuals. Dall (1921, pl. 5) figured the superimposed life-size outlines of 28 modern specimens of *M.* (*A.*) *elegans* from Chignik Bay, Alaska Peninsula, to usefully illustrate the variation in shell outline found in a single population. However, there seem to be no modern individuals of *M.* (*A.*) *elegans* that have the elevated trigonal shell and small posterior gape of the Alaskan Tertiary fossil forms.

The nomenclatural history of this species is somewhat confused. The type specimens of *M. crassa* Grewingk, 1850, were Tertiary fossils reported to come from Pavlof, a now-abandoned Aleut Indian village or camp on the east side of Pavlof Bay (Orth, 1967, p. 743), along the Pacific coast of the Alaska Peninsula about 120 km northeast of Cape Tachilni (Text-figs. 2, 3). The only Tertiary strata in the environs of Pavlof are Paleocene or Eocene rocks of the Tolstoi Formation (Burk, 1965), which are not a possible source for *M. crassa*. As suggested by MacNeil (1965, p. G30), Pavlof was probably only a base of operations for Europeans, and specimens of *M. crassa* probably were carried there from elsewhere on the Alaska Peninsula. After learning that the type specimens of *M. crassa* had been lost from the Zoological Institute in Leningrad, MacNeil (1965, p. G30, pl. 2, fig. 3) designated a neotype from beds of presumed Pliocene age along Yellow Bluff Creek, near Black Peak, Alaska Peninsula, about 330 km northeast of Cape Tachilni (Text-fig. 2). Tertiary beds at Yellow Bluff Creek are now assigned to the Bear Lake Formation and thought to be of middle or late Miocene age. MacNeil (1965, p. G30, pl. 2, fig. 7) also designated a neotype from the same lot for *M.* (*A.*) *elegans*. In effect, MacNeil (1965) fixed the morphologic concepts of *M. crassa* Grewingk (a homonym) and *M.* (*A.*) *elegans,* based on neotype specimens from the same locality in the Bear Lake Formation at Yellow Bluff Creek. It is not known whether one or two species of *Mya* occur in the Yellow Bluff Creek beds, due to sparse collecting and the wide variation in shell form of specimens of *Mya* collected there. Further study may show the two named species from Yellow Bluff Creek to be synonymous. Until then, it seems best to retain *M.* (*A.*) *elegans* for Tachilni specimens, because this name is well-established in the modern literature, in contrast to Grewingk's (1850) obscure homonym, *M. crassa*.

Mya (*Arenomya*) *elegans* has been reported as a fossil only on the Alaska Peninsula, the Aleutian Islands, and Kodiak Island. Grewingk (1850) gave records from Kodiak and Unga Islands, from the Aleutian Islands of Atka [as "?"] and Unalaska, and from the Alaska Peninsula at Pavlof, Morzhovoi Bay, and Port Moller. He also obscurely referred to a specimen from near Capę Romanzof in the northeastern Bering Sea, but it is unclear if this is a modern or fossil shell. Eichwald (1871) also cited its presence on Kodiak and Unalaska Islands. MacNeil (1965, p. G30) cautioned that some of these older records may be based on species other than *M.* (*A.*) *elegans,* and added several Alaskan Miocene to Holocene localities to the known

occurrences. This species has been reported twice before from the Tachilni Formation (Marincovich *in* McLean, Englehardt, and Howell, 1978; Allison, 1978).

No precise bathymetric data have been published for *M.* (*A.*) *elegans,* though the species apparently lives only in relatively shallow water, as do other species of *Mya*. Bernard (1979b, p. 199) noted that the species is "rarely collected because of its deep infaunal habitat and its absence from the intertidal and extreme shallow water zones." Bernard (1979b, p. 185) stated that individuals of the genus may be present at depths of "100 m or more," though he provided no documentation, and a more widely accepted figure for maximum living depth of species of *Mya* is 50 m (Keen and Coan, 1974). All Tachilni specimens are articulated, closed individuals that suggest little or no postmortem transport.

Type information.—Type specimen(s): [of *M.* (*A.*) *elegans*] lost from ZIL (MacNeil, 1965). Neotype: USNM 644272 (designated by MacNeil, 1965). Type locality: (of neotype): USGS locality M807a, beds on east side of Yellow Bluff Creek, near the headwaters, about 45 km south of Port Heiden, Alaska Peninsula; Bear Lake Formation; middle or upper Miocene.

Tachilni Formation occurrence.—USGS locality M5163 (1 specimen), M5166 (3 specimens), M7139 (1 specimen), M7141 (1 specimen), M7146 (1 specimen), M7149 (11 specimens, 2 valves), M7202 (1 specimen); UA locality A-170 (2 specimens).

Figured specimens.—USNM 339807, 339808.

Stratigraphic and geographic range.—This species is cited in middle or upper Miocene to Holocene faunas, but there are no verified reports from Pliocene strata. Middle or upper Miocene: Bear Lake Formation at Yellow Bluff Creek (MacNeil, 1965; USGS coll.) and at Bear Lake (formational type section; USGS coll.), Alaska Peninsula; Narrow Cape Formation type section, Narrow Cape, Kodiak Island (USGS and UA coll.). Lower upper Miocene: Tachilni Formation, Cape Tachilni, Alaska Peninsula (Marincovich *in* McLean, Englehardt, and Howell, 1978; Allison, 1978). Reputed Miocene occurrences in the Aleutians on Atka Island (Grewingk, 1850, as "?") and Unalaska Island (Grewingk, 1850; Eichwald, 1871), as well as on the Alaska Peninsula at Pavlof, Port Moller and Morzhovoi Bay (Grewingk, 1850), require confirmation; the Port Moller report probably is from the Bear Lake Formation and the Morzhovoi Bay report probably is from the Tachilni Formation. Middle (?) Pleistocene: unnamed strata on St. Paul Island, Pribilof Islands (MacNeil, 1965) and on St. Lawrence Island, Bering Sea (Hopkins, Rowland, and Patton, 1972). Holocene: Reported northern record is in the eastern Bering Sea, in Kuskokwim Bay north of Cape Newenham (MacNeil, 1965), but newer USGS collections contain beach-drift shells from as far north as Nokolek in the eastern Chukchi Sea at latitude 70°19′57″N; also reported from the Pribilof Islands and on the Pacific side of the Alaska Peninsula at Chignik and Kukak Bays (MacNeil, 1965) and northward as far as Cook Inlet (Bernard, 1979b).

Mya new species?
Plate 21, figures 4–9

Discussion.—This Tachilni taxon is characterized by a relatively elongate shell having a produced posterior end that has a moderate gape and flared margins. The posterior margin is bluntly rounded to subtruncate, compared to the broadly rounded anterior margin. The anterior dorsal margin is convex and slightly raised, the umbo is slightly elevated, and the posterior dorsal margin is depressed and straight to slightly concave. The ventral margin is straight to weakly convex and roughly parallel to the dorsal margin. The valves are only moderately inflated and their sculpture consists only of fine to coarse, irregularly spaced concentric growth lines. Of the two Tachilni specimens, one (Pl. 21, figs. 7–9) has its beaks nearly central but set very slightly to the anterior, and the other (Pl. 21, figs. 4–6) has its beaks set a greater distance to the posterior of the shell center line. One specimen has a length of 55.4 mm and height of 29.0 mm and the other has a length of 50.2 mm and height of 27.0 mm.

Among the large number of described species of *Mya* in the North Pacific (Clark, 1932; Nagao and Inoue, 1941; Krishtofovich and Ilyina, 1954; Fujie, 1957a, 1957b; Ilyina, 1963; MacNeil, 1965; Strauch, 1972), this species seems most closely related to *M.* (*M.*) *truncata* Linnaeus, 1758, *M.* (*M.*) *salmonensis* Clark, 1932, and *M.* (*M.*) *majanatschensis* Ilyina, 1963. The moderately large gape and flared posterior margins ally the Tachilni taxon with *M.* (*M.*) *truncata,* although *Mya* n. sp.? is distinctly less inflated, smaller in size, relatively more elongate, and lacks the truncated posterior end of *M.* (*M.*) *truncata*. *Mya* (*Mya*) *salmonensis,* described from Oligocene rocks of the Poul Creek Formation in the northeastern Gulf of Alaska, is of similar size and elongate proportions to the Tachilni taxon (Clark, 1932; MacNeil, 1965), but is known from few specimens, making comparisons with other species difficult. The holotype and paratype of *M.* (*M.*) *salmonensis* (Clark, 1932, pl. 17, figs. 3, 4, 8; refigured by Addicott *et al.,* 1971, figs. 5i, p, q, t, w) differ from the Tachilni specimens by having posterior ends with only a slight gape and unflared margins, a more inflated shell with a more elevated umbo, and a much more

steeply sloping posterior dorsal margin. The types of *M.* (*M.*) *salmonensis* also have umbones relatively much closer to their anterior ends than do the Tachilni specimens. A specimen of *M.* (*M.*) *salmonensis* figured by MacNeil (1965, pl. 7, figs. 1, 4) is very similar to Clark's (1932) figured types, but differs by having a lower umbo and less steeply sloping and relatively more elongate posterior end. Thus, the posterior end of MacNeil's (1965) figured specimen is more similar to that of the Tachilni taxon than to Clark's (1932) types. However, MacNeil's (1965) specimen clearly lacks the flared posterior margin that is such a prominent feature of the Tachilni taxon.

The specimens here assigned to *Mya* n. sp.? are also similar in form to one figure (a paratype?) of *M.* (*M.*) *majanatschensis* Ilyina, 1963 (pl. 31, fig. 5), a species known from middle or upper Miocene strata of the Kakert Formation of western Kamchatka. Ilyina (1963, p. 85) reported *M.* (*M.*) *majanatschensis* occurring in "large numbers" with *Macoma optiva* (Yokoyama, 1923), which is a common Tachilni bivalve. The holotype and most other illustrated specimens of *M.* (*M.*) *majanatschensis* Ilyina (1963, p. 84–85, pl. 31, figs. 1, 3, 4, 6, 7) clearly differ from the Tachilni specimens of *Mya* by having strongly elevated umbones set very close to the anterior end of the shell, a relatively elevated shell outline with strongly concave posterior dorsal margins and moderately convex ventral margin, and more strongly inflated valves. Both species have similar posterior ends, with moderate gape and flared margins. However, one of Ilyina's specimens (1963, pl. 31, fig. 5) resembles *Mya* n. sp.? by having elongate proportions, a relatively low (and apparently somewhat worn) umbo set slightly anterior of the shell center line, and a nearly straight ventral margin. It is possible that the Tachilni taxon falls within the morphologic range of *M.* (*M.*) *majanatschensis*, and equally likely that Ilyina's (1963, pl. 31, fig. 5) specimen and the Tachilni specimens belong to another, possibly undescribed species.

Both specimens of *Mya* n. sp.? have articulated, closed valves as evidence for little or no post-mortem transport.

Tachilni Formation occurrence.—UA locality A-301 (2 articulated, closed specimens).

Figured specimens.—UA 2487, 2488.

Family **HIATELLIDAE** Gray, 1824

Genus **PANOMYA** Gray, 1857

Panomya izumo Nomura and Hatai, 1939
Plate 21, figure 11

Panomya izumo Nomura and Hatai, 1939, p. 6, figs. 2a, b; Strauch, 1972, p. 65, pl. 4, fig. 2.

Discussion.—This bivalve is one of the rarest in North Pacific Tertiary faunas. It was previously known from one formation in southwestern Honshu, and the Tachilni occurrence is its first outside Japan. The shell of *P. izumo* is relatively short and less quadrate than other species of *Panomya* (Strauch, 1972), and has a broadly and evenly rounded anterior end, slight anterior placement of the umbo, and obliquely truncated posterior end. The posterior end is distinctive because of the broadly rounded and somewhat produced posterior ventral margin, narrow posterior dorsal angulation, and the "backward" slope of the posterior truncation (*i.e.*, the dorsal shell margin is shorter than the ventral margin). Illustrations of the holotype of *P. izumo* show a moderately elevated umbo, which is not clearly seen, but is suggested, on the slightly crushed Tachilni specimens. Sculpture of both Japanese and Alaskan specimens consists only of coarse, irregularly spaced concentric growth lines that crowd together at the posterior dorsal angle. The holotype, and only previously illustrated specimen, of *P. izumo* is 54.5 mm long and 41.0 mm high (Nomura and Hatai, 1939). The most complete Tachilni specimen is 73.3 mm long and 52.4 mm high. A second and far less complete Tachilni specimen is about 45 mm high.

Panomya izumo is not close in form to any other species. *Panomya chrysis* Dall, 1909, a coeval North American species, described from a single mold in the Wishkahan fauna of the Empire Formation at Coos Bay, Oregon (Dall, 1909, p. 133–134, pl. 11, fig. 7), differs from *P. izumo* by having a truncate posterior end that slopes in the opposite direction, a straight rather than broadly curved ventral margin, and a convex rather than concave posterior dorsal margin. According to Strauch (1972, p. 78, fig. 12), *P. izumo* is descended from *P. chrysis*.

The original citation of *P. izumo*, repeated by Strauch (1972), is the only record of the species known to me. Subsequent study of the molluscan fauna of the Fujina Formation (Ogasawara and Nomura, 1980) produced no new specimens. Modern catalogs of Japanese Tertiary mollusks (Hatai and Nisiyama, 1952; Masuda and Noda, 1976) also include no further mention of *P. izumo*.

Panomya is a northern cool-water genus, known from depths of five to 300 m in western North America (Keen and Coan, 1974). Both Tachilni specimens have articulated and closed valves, suggesting little or no post-mortem transport.

Type information.—Holotype: GS, No. 51884. Type locality: Izumo, Shimane Prefecture, southwestern Honshu, Japan; Fujina Formation; upper Miocene.

Tachilni Formation occurrence.—USGS localities

M7143 (1 articulated, closed specimen), M7146 (1 articulated, closed specimen).

Figured specimen.—USNM 339809.

Stratigraphic and geographic range.—This species was previously reported only from upper Miocene strata of the Fujina Formation, Izumo, Shimane Prefecture, southwestern Honshu, Japan (Nomura and Hatai, 1939).

Panomya trapezoidis Strauch, 1972
Plate 21, figure 12

Panomya trapezoidis Strauch, 1972, p. 61–62, 70–74, pl. 4, figs. 1, 3–12, text-figs. 10a–10n, 10s–10v.

Panomya (*Panomya*) cf. *P.* (*P.*) *trapezoides* [sic] Strauch. Gladenkov, Norton, and Spaink, 1980, p. 60, pl. 10, figs. 11–14.

Discussion.—The single well-preserved specimen of *Panomya trapezoidis* in the Tachilni fauna closely resembles several specimens figured by Strauch (1972), although it is not identical in form to his figure of the holotype. The shell outline of *P. trapezoidis* is extremely variable, however, and Tachilni specimens fall within the morphologic limits noted by Strauch (1972). The best-preserved Tachilni specimen is 48.7 mm long and 27.6 mm high, slightly smaller and more elongate than average for specimens measured by Strauch (1972, p. 67). The posterior margin of Tachilni specimens is shallowly concave, and the posterior dorsal margin is produced, as is common in *P. trapezoidis*. The anterior margin of the best-preserved Tachilni specimen is somewhat narrowly rounded, a feature that occurs in about half of the individuals figured by Strauch (1972). The central part of the best-preserved Tachilni specimen is slightly concave and separated from the anterior and posterior portions of the shell by two radial ridges. This central concavity seems to occur in all specimens illustrated by Strauch (1972), but the development of radial ridges appears to vary widely, with many individuals lacking them.

Panomya trapezoidis is among the most variable species in a genus noted for infraspecific variability. Roth (1979, p. 395) suggested possible synonymy of *P. trapezoidis* with *P. chrysis* Dall, 1909, described from the upper Miocene Empire Formation at Coos Bay, Oregon. *Panomya* cf. *P. chrysis,* so identified by Roth (1979, p. 392) occurs in lower and upper Pleistocene strata of northwest California and southwest Oregon, and resembles *P. trapezoidis* except for having a generally stronger flexure or re-entrant along the posterior margin (Roth, 1979, p. 393).

Strauch (1972, p. 64) cited the oldest occurrence of *P. trapezoidis* in presumed upper Oligocene rocks of the Poul Creek Formation in the Cape Yakataga area, south-central Alaska, based on Clark's (1932, p. 832, pl. 17, figs. 6, 7, 9) report of "*Panomya* (*Arctica*) *turgida* Dall" and "*Panomya* n. sp." there. Clark's (1932) two taxa were reported from a total of five localities near Cape Yakataga, but none of these was assigned with certainty to the Poul Creek Formation by Addicott *et al.* (1971, p. C19) and one was placed in the lower Yakataga Formation. Kanno (1971, p. 95) reported "*Panomya arctica*" from the Yakataga but not the Poul Creek Formation near Cape Yakataga, and Ariey (1978, p. 114) collected "*Panomya arctica*" from two localities in the upper Poul Creek Formation, as well as in the Yakataga Formation, near Cape Yakataga. In USGS collections from the Yakataga area, *P. trapezoidis* is present only in the Yakataga Formation fauna. Because the boundary between the Poul Creek Formation and overlying Yakataga Formation appears to be time-transgressive (McCoy and Marincovich, 1980), the uppermost Poul Creek strata may be of late Oligocene age at one locality and perhaps as young as early middle Miocene age at another. Thus, the age of the first occurrence of *P. trapezoidis* is not known with certainty, and the species may not occur in strata as old as Oligocene.

Strauch (1972) reported many Miocene through lower Pleistocene occurrences in California, the Pacific Northwest, and Europe, and cited a modern range from Kodiak Island, western Gulf of Alaska, to the Puget Sound region, Washington (Text-fig. 1). Many additional literature records of species of *Panomya* in the eastern North Pacific need to be reevaluated for possible assignment to *P. trapezoidis*.

Living species of *Panomya* in the eastern North Pacific are reported from depths of five to 300 m by Keen and Coan (1974).

Type information.—Holotype: SMF, No. SMF 2200996. Type locality: horizon 15/1 of the upper Westtjörnes Beds, Hallbharnarstadakambur, Tjörnes, north Iceland; Pleistocene.

Tachilni Formation occurrence.—USGS locality M7150 (1 valve); UA locality A-169 (1 articulated, closed specimen, as "cf.").

Figured specimen.—USNM 339810.

Stratigraphic and geographic range.—This species ranges from upper Oligocene or lower Miocene to Holocene. Upper Oligocene (?): Poul Creek Formation, near Cape Yakataga, south-central Alaska (Ariey, 1978). Lower Miocene: Poul Creek and Yakataga Formations, near Cape Yakataga, south-central Alaska (Clark, 1932; Kanno, 1971; Ariey, 1978). Reported by Strauch (1972, text-fig. 13) in Miocene to lower Pleistocene deposits of California, Oregon, Washington, Iceland, England, and the Netherlands. Holocene: Kodiak Island, western Gulf of Alaska, to Puget Sound region, Washington (Strauch, 1972).

Family **PANDORIDAE** Rafinesque, 1815

Genus **PANDORA** Bruguiere, 1797

Subgenus **PANDORELLA** Conrad, 1863

Pandora (Pandorella) grandis Dall, 1877
Plate 21, figure 10

Pandora (*Kennerlia*) *grandis* Dall, 1877, p. 5; Oldroyd, 1924, vol. 1, p. 87–88, pl. 15, fig. 10; Grant and Gale, 1931, p. 261–262, pl. 13, figs. 5a, 5b.
Pandora wajampolkensis Slodkewitsch, 1935, p. 304–306, pl. 29, figs. 3a, 3b; Slodkewitsch, 1938a, p. 272–273; Slodkewitsch, 1938b, p. 126–127, pl. 59, figs. 1a, 1b.

Discussion.—The relatively large size and very broadly rounded and expanded posterior end distinguish this species from other North Pacific species of *Pandora*. The single Tachilni specimen, at 37.5 mm long and 26.2 mm high, is of typical size for *P.* (*P.*) *grandis*. The species is further characterized by a prominent radial flexure that extends from the umbo to the anterior ventral margin, lack of sculpture other than concentric growth lines, and a straight to slightly convex posterior dorsal margin. Most other species of *Pandora* have a more strongly concave posterior dorsal margin.

There are numerous living North Pacific species of *Pandora* (Dall, 1921; Oldroyd, 1924), but *P.* (*P.*) *grandis* is not easily confused with the others. Boss and Merrill (1965, p. 181) note that *Pandora* is a cosmopolitan genus with a preference for cooler waters of the northern hemisphere, and that it is most highly differentiated along the coasts of eastern Asia, and western and eastern North America. Roth (1979, p. 403) cites the living Alaskan species *P. forresterensis* (Willett, 1918) as a junior synonym of *P.* (*P.*) *grandis*, and evidently is also the first to place the latter species in *Pandorella*.

The Tachilni specimen of *P.* (*P.*) *grandis* is the only verified Miocene occurrence of this species in North America. Dall (1896, p. 845) reported this species in "Miocene" rocks of St. Paul Island, Pribilof Islands, Bering Sea, but this occurrence is of Pliocene or Pleistocene age. Based on its synonymy with *P. wajampolkensis* Slodkewitsch, 1935, noted here for the first time, *P.* (*P.*) *grandis* occurs in the "upper horizon" of the Vayampol Group in western Kamchatka (Slodkewitsch, 1938a, p. 272; 1938b, p. 127). In modern usage, this stratigraphic interval is equivalent to the Viventek and Kuvulen Formations, and is assigned an age of about early Miocene (Menner, Baranova, and Zhidkova, 1977; Gladenkov, 1980). Slodkewitsch's (1938b) illustrations show typical examples of *P.* (*P.*) *grandis*, but the occurrence of this species in western Kamchatka needs verification, because it has not been cited from there in later Russian works (Ilyina, 1963; Gladenkov, 1972). There are no certain Pliocene reports of this species, although Grant and Gale (1931, p. 262) refer to possible Pliocene occurrences in northern California.

Data on the habitat of modern *P.* (*P.*) *grandis* are scant. Kennedy (1978, p. 501) cites a depth range of 18 to 372 m, in mud or sand, and *P.* (*P.*) *grandis* has been collected at Wrangell, southeastern Alaska, from a mud bottom at 91 m depth (Burch, 1944, No. 37, p. 16). The genus is reported in depths of five to 400 m in the eastern Pacific (Keen and Coan, 1974).

Type information.—Holotype: USNM 171069. Type locality: Unalaska Island, Aleutian Islands, Alaska; Holocene.

Tachilni Formation occurrence.—USGS locality M7139 (1 valve).

Figured specimen.—USNM 339811.

Stratigraphic and geographic occurrence.—This species ranges from the lower Miocene (?), Pliocene or Pleistocene to Holocene. Lower Miocene (?): upper Vayampol Group, Belogolovaya River, western Kamchatka (Slodkewitsch, 1935, 1938a, 1938b). Pliocene or Pleistocene: St. Paul Island, Pribilof Islands, Alaska (Dall, 1896). Lower Pleistocene: Rio Dell Formation (Roth, 1979) and type Merced Formation (Martin, 1916), northern California; Anchor Silt (Rodda, 1957) and San Pedro Formation (Clark, 1931; Woodring, Bramlette, and Kew, 1946; Valentine, 1961), southern California. Upper Pleistocene: deposits in lower Fraser Valley and Vancouver Island, British Columbia, Canada (Wagner, 1959); Elk River Formation, southwestern Oregon (Roth, 1979). Holocene: Pribilof Islands, Bering Sea, Alaska, to Siletz Bay, Oregon (Dall, 1921).

Family **LYONSIIDAE** Fischer, 1887

Genus **LYONSIA** Turton, 1822

Lyonsia mooreae new species
Plate 22, figures 1–4

Diagnosis.—Shell small for the genus, with a short and sharply truncated posterior end, straight to slightly convex dorsal margins, and fine radial costellae made up of microscopic beads.

Description.—Shell ovate in outline, with a broadly and evenly rounded anterior end and a very slightly produced posterior end that is abruptly truncated; ventral margin evenly rounded, anterior and posterior dorsal margins straight to slightly convex, umbo moderately elevated; posterior dorsal portion of shell somewhat flattened and set off by a low angulation that extends from the umbo to the posterior ventral margin. Left valve slightly smaller than right with its

umbo set below that of the right valve. Sculpture on each valve consists of fine, irregular concentric growth lines and very fine radial costellae; radial costellae are best developed on central portion of each valve and are missing from anterior one-third of valve and from flattened posterior dorsal area; costellae are separated by interspaces most commonly of greater, but rarely of equal width; radial costellae consist of closely spaced microscopic beads that are most distinct toward the ventral margin; on the proximal portion of each valve, these microscopic beads coalesce into a virtually continuous, intermittently beaded thread; costellae are absent from umbones, evidently due to erosion during life. Posterior gape narrow but distinct. Largest specimen too poorly preserved for accurate measurement, but is close in size to the holotype, which is 14.9 mm long and 10.0 mm high; smallest specimen is 10.0 mm long and 7.3 mm high.

Discussion.—Four specimens of *Lyonsia mooreae* n. sp. are present in a single hand sample of Tachilni sandstone and comprise the first occurrence of *Lyonsia* as a fossil in Alaska. Each of the four individuals has articulated and closed valves, and the long axes of the shells are nearly in parallel alignment.

Lyonsia mooreae n. sp. is most similar in form to the living Japanese species *L. teramachii* (Habe, 1952). The latter species was proposed as the type-species of *Bentholyonsia* Habe, 1952, which was later considered to be a junior synonym of *Lyonsia* by Prezant (1981, p. 68). *Lyonsia teramachii* is similar in adult shell outline to *L. mooreae*, but differs by being larger (up to 22.5 mm long and 15.8 mm high: Habe, 1952, 1958), having a concave rather than straight or convex posterior dorsal margin, and having its beaded radial costellae more strongly expressed as well as covering the whole valve exterior. Judging from the young specimen of *L. teramachii* figured by Kuroda, Habe, and Oyama (1971, p. 478, pl. 121, fig. 18), juveniles equal in size to *L. mooreae* are more elongate, with higher umbones and less sharply truncated posterior ends.

The geographic range of *L. teramachii* is from Shikoku, southern Japan, to the Boso Peninsula, central Honshu, and it occurs on fine-sand bottoms at 20 to 200 m depth (Kuroda, Habe, and Oyama, 1971, p. 478).

Etymology.—This species is named in honor of Ellen J. Moore, my colleague at the U.S. Geological Survey, Menlo Park, California.

Type information.—Holotype: USNM 339812. Paratypes: USNM 339813, 353151, 353152. Type locality: USGS M7142, one m above base of measured stratigraphic section at Cape Tachilni (Text-figs. 3, 4); approximately 91 m (300 ft) east of southwest corner section 31, T. 60 S, R. 89 W, on south boundary of section, False Pass (D-3) quadrangle, Alaska Peninsula, Alaska; collected by L. Marincovich, Jr., June 1977.

Tachilni Formation occurrence.—USGS locality M7142 (4 articulated, closed specimens).

Figured specimens.—USNM 339812 (holotype); 339813 (paratype).

Stratigraphic and geographic range.—Known only from its type locality.

Family **PERIPLOMIDAE** Dall, 1895

Genus **PERIPLOMA** Schumacher, 1817

Subgenus **PERIPLOMA** Schumacher, 1817

Periploma (Periploma) cf. **P. (P.) aleutica**
(Krause, 1885)
Plate 22, figures 5–9

Anatina? aleutica Krause, 1885, p. 38–39, pl. 3, fig. 7.
Periploma (Periploma) aleutica (Krause). Bernard, 1979a, p. 59, fig. 104.
Periploma alaskana Williams, 1940, p. 37, fig. 1.

Discussion.—Tachilni specimens of *Periploma* cf. *P. aleutica* have a broadly rounded anterior end, and an evenly curved ventral margin, with the posterior end produced, truncated and set off by a broad and shallow radial sulcus. The posterior dorsal margin is slightly concave, the umbo moderately elevated, and the anterior dorsal margin slightly convex. The main difference in shape between these and typical specimens of *P. aleutica* is that the latter has a more evenly rounded and broadly expanded posterior ventral margin. The posterior ventral margin of Tachilni specimens is more narrowly produced (though not to a uniform degree among individuals) than in typical specimens of *P. aleutica*. Tachilni specimens evidently are larger than modern individuals of *P. aleutica* from the western Beaufort Sea, where the largest was cited by Bernard (1979a, p. 60) as being 36.8 mm long. Dimensions of the best-preserved Tachilni specimens are:

	UA 2489	Two unnumbered specimens from USGS locality M7140		USNM 339815
Length:	52.8 mm	41.4 mm	38.4 mm	38.1 mm
Height:	39.0 mm	32.1 mm	27.8 mm	28.2 mm

This Tachilni taxon is virtually identical in shell form to several North Pacific species of *Thracia* Leach *in* Blainville, 1824, that occur in middle Tertiary to Holocene faunas (illustrated in Oldroyd, 1924, and Ka-

mada, 1955). However, most well-preserved Tachilni specimens have slightly eroded umbonal areas, where the trace of an internal buttress is clearly visible, radiating a short distance from the beak to the posterior ventral margin (Pl. 22, figs. 7, 9). *Periploma* has such a buttress supporting a chondrophore, whereas *Thracia* lacks both. All Tachilni specimens also show the unmistakable presence of a nacreous interior shell layer where the valve exteriors are worn, which is another feature of *Periploma* not present in *Thracia*.

At least 32 Cenozoic species of *Periploma* have been described from the North Pacific. Even though Tachilni specimens seem to be closest to *P. aleutica*, the morphologic variability of some species of *Periploma* makes species-level taxonomy uncertain. For example, the only previously reported Tertiary species of *Periploma* from Alaska, *Periploma* (*Aelga*) *besshoense* (Yokoyama, 1924), has a posterior margin that varies from broadly rounded to rostrate (Kamada, 1962, p. 76; Kanno, 1971, p. 97). Tachilni specimens tentatively assigned to *P. aleutica* may eventually turn out to be one of several middle Tertiary Asiatic species.

Periploma aleutica is known to live in Alaskan waters, from the northern Gulf of Alaska to the western Beaufort Sea (Bernard, 1979a, p. 59). Dead specimens from the western Beaufort Sea were found in 709 m depth (Bernard, 1979a). *Periploma* is a distinctly cold-water element in the Tachilni fauna. The genus is reported to range from 20 to 90 m depth in the northeastern Pacific (Keen and Coan, 1974). The present record is the first report of *P. aleutica* as a possible fossil. The fact that the thin, edentulous shells of all Tachilni specimens are articulated and closed is strong evidence for lack of post-mortem transport.

Type information.—Holotype: location unknown. Type locality: southern Bering Sea, north of Akutan Pass, Aleutian Islands, Alaska [between Akutan and Unalaska Islands], at depth of 70 fms (Krause, 1885).

Tachilni Formation occurrence.—USGS localities M7140 (2 articulated, closed specimens), M7146 (1 articulated, closed specimen); UA locality A-170 (3 articulated, closed specimens).

Figured specimens.—USNM 339814, 339815; UA 2489.

Stratigraphic and geographic occurrence.—Tachilni Formation specimens are the first reported fossils of this species. Modern occurrences are reported from Montague Island, northern Gulf of Alaska, and the Chukchi Sea (Williams, 1940), as well as the southern Bering Sea (Krause, 1885) and western Beaufort Sea (Bernard, 1979a).

Class **GASTROPODA** Duméril, 1806

Family **TROCHIDAE** Rafinesque, 1815

Genus **MARGARITES** Gray, 1847

Subgenus **PUPILLARIA** Dall, 1909

Margarites (Pupillaria) new species?

Plate 22, figures 10–15

Discussion.—Two Tachilni specimens match the definition of *Margarites* (*Pupillaria*) given in Keen and Coan (1974): they are turbinate and umbilicate, have a nacreous interior and sculpture only of spiral riblets, and are "medium-sized" (6 to 20 mm in diameter). The largest and best-preserved Tachilni specimen is 9.1 mm high and 11.2 mm in diameter and has five-and-one-half whorls, of which four show spiral sculpture. The spiral costellae are slender, slightly flattened, only slightly raised, and are separated by smooth interspaces of somewhat greater width. Ten costellae are visible on the penultimate whorl and about 18 on the body whorl above the broadly rounded periphery. On all earlier whorls the costellae are more widely spaced immediately below the suture and more closely bunched on the anterior part of the whorl. However, costellae on the body whorl, especially its anterior half, are more or less evenly spaced and separated by interspaces of equal or lesser width. Below the periphery, costellae also number about 18 and become relatively wider toward the umbilicus. The umbilicus is broadly open and circular in basal view. Nacreous shell material is visible where the exterior surface is decorticated.

More than a dozen species of *Margarites, s.l.,* are known from high-latitude North Pacific middle Tertiary faunas (Weaver, 1942; Hatai and Nisiyama, 1952; Masuda and Noda, 1976), and a similar number of Holocene species of *Margarites* (*Pupillaria*) occur in the same region (Dall, 1921). The Tachilni species is difficult to compare to described taxa, because of inadequate illustrations and descriptions accompanying some of the latter. It does not seem to be identical to any known Holocene species.

The one species of *Margarites* previously reported from Alaska Peninsula Tertiary rocks is *M. peninsularis* Dall, 1904 (p. 110–111, pl. 9, fig. 6), described from Oligocene strata of the Stepovak Formation (MacNeil *in* Burk, 1965, p. 224). Relatively large at a height of 12 mm, *M. peninsularis* has spiral sculpture consisting only of a peripheral keel and one or two much weaker costellae (Dall, 1904, and USGS coll.), so is clearly distinct from the Tachilni species. The only other known Alaskan Tertiary species of *Mar-*

garites, "*Margarites* sp. nov. cf. *M. chappelli* Durham, 1944," reported in Miocene rocks of the Yakataga Formation in the northeastern Gulf of Alaska by Ariey (1978, p. 121–122, pl. 1, fig. 6), differs from the Tachilni species by having a smooth exterior. *Margarites chappelli*, a late Eocene species from Washington, also has a smooth exterior (Durham, 1944, p. 154). Among northwestern Pacific Tertiary species of *Margarites*, the Tachilni taxon is most similar to *M.* (*P.*) *sinzi* Nomura and Hatai, 1939, which is found only in upper Miocene strata of the Fujina Formation in Shimane Prefecture, southwestern Honshu (Ogasawara and Nomura, 1980, p. 85, pl. 12, figs. 4a–c). The two species have similar sizes, proportions, whorl profiles, and broadly open umbilici, but the Tachilni species is characterized by more numerous spiral costellae. The Fujina species is reported to have six costellae on the penultimate whorl and five above the periphery of the body whorl, whereas the Tachilni taxon has 10 and 18 costellae, respectively. Fine secondary costellae are evidently present in the interspaces of the body whorl above the periphery of *M.* (*P.*) *sinzi*, whereas secondary costellae are absent from the Tachilni species.

A bathymetric range of 0–230 m for modern *Margarites*, *s.l.*, of the eastern Pacific is given by Keen and Coan (1974).

Tachilni Formation occurrence.—USGS locality M7146 (1 adult); UA locality A-170 (1 adult).

Figured specimens.—USNM 339816; UA 2490.

Stratigraphic and geographic range.—So far as known, this species is unique to the Tachilni fauna.

Family **CALYPTRAEIDAE** Schumacher, 1817

Genus **CALYPTRAEA** Lamarck, 1799

Calyptraea species indeterminate
Plate 22, figures 16, 17

Discussion.—The single Tachilni specimen of *Calyptraea* consists mostly of an incomplete internal mold. A small matching fragment of external mold bearing some shell material shows that the exterior surface is smooth except for obscure growth lines.

The only previous report of a Tertiary species of *Calyptraea* from the Alaska Peninsula is by MacNeil (*in* Burk, 1965, p. 226, 227). He noted an indeterminate species in rocks of the Stepovak Formation southeast of Stepovak Bay, Alaska Peninsula, to which he assigned an age of "Oligocene, probably middle or late." This specimen, in the USGS collections at Menlo Park, is an external mold that approximates the shape, size and smooth exterior of the Tachilni species. MacNeil (*in* Burk, 1965, p. 227) further noted "*Calyptraea* cf. *C. alaskana* (Dall) and *C. tokunagai* Hatai and Nisiyama" from the Stepovak Formation on Unga Island. MacNeil's "*C. alaskana*" probably refers to *Trochita alaskana* Dall, 1904 (p. 118–119, pl. 10, figs. 2, 6), described from the Oligocene Stepovak Formation on Unga and Popof Islands. Dall's (1904) original description and figures indicate a high-spired gastropod very unlike the Tachilni specimen of *Calyptraea* and probably assignable to a different genus. *Calyptraea tokunagai* Hatai and Nisiyama, 1952 (p. 118) [*non* Hiriyama, 1955, p. 116, as stated by Masuda and Noda, 1976, p. 13; ICZN, 1961, Art. 13(a)iii] is reported in Oligocene beds of the Asagai Formation in Fukushima Prefecture, northeastern Honshu. It has a flat conical shell bearing fine spiral striae and a nearly central apex (Yokoyama, 1924; Masuda and Noda, 1976). The fine spiral striae of *C. tokunagai* seem to distinguish it from the Tachilni species.

In the northeastern Gulf of Alaska, Kanno (1971, p. 108) cited a specimen of *Calyptraea* in the upper part of the Poul Creek Formation in the Yakataga district, presumably in strata of Oligocene or early Miocene age. Kanno (1971, pl. 12, figs. 5, 6) illustrated coarse, obscure radiating ribs on the specimen from Poul Creek. These ribs separate it from the smooth-surfaced Tachilni and Stepovak specimens.

The specimens of *Calyptraea* from the Tachilni and Stepovak Formations that I have examined are similar to the better-preserved specimen of "*Calyptraea* sp." figured by Addicott (1978, p. 680, fig. 5k) from the Skonun Formation of British Columbia, Canada. The Skonun fauna was correlated with the Wishkahan Stage by Addicott (1978) and assigned an early late Miocene age.

Species of *Calyptraea* are said to live in warm to temperate regions (Kanno, 1971), but one modern eastern Pacific species has been reported as far north as Port Etches, Hinchinbrook Island, northern Gulf of Alaska, at 60°20′N latitude (Dall, 1921, p. 163). A depth range for eastern Pacific *Calyptraea* of intertidal to 140 m was given by Keen and Coan (1974).

Tachilni Formation occurrence.—UA locality A-170 (1 young adult).

Figured specimen.—UA 2491.

Stratigraphic and geographic range.—The present specimen of *Calyptraea* is the first of that genus reported from the Tachilni Formation, and the first certain report of the genus in Alaskan rocks younger than Oligocene.

Family **NATICIDAE** Forbes, 1838

Genus **POLINICES** Montfort, 1810

Subgenus **EUSPIRA** Agassiz *in*
J. Sowerby, 1838

Polinices (Euspira) diabloensis (Clark, 1915)
Plate 22, figure 19

Natica (*Euspira*) *diabloensis* Clark, 1915, p. 486–487, pl. 68, fig. 7.
Polinices (*Euspira*) *diabloensis* (Clark). Marincovich, 1977, p. 267–269, pl. 23, fig. 10.

Discussion.—This uncommon species is more elongate than average for a naticid, and has a relatively elevated spire. The umbilicus is narrowly open and bounded by a broad cordlike angulation on the base of the shell. The umbilical callus is narrow and not clearly set off from the inner lip. The parietal callus is thick, solidly fills the posterior apertural angle, and has a weak anterior lobe that projects slightly above the umbilicus. An average specimen of *P.* (*E.*) *diabloensis* is 45 mm high and 37 mm in diameter, based on measurements of 13 specimens (Marincovich, 1977).

A single Tachilni specimen bears the distinctively elongate shape, elevated spire, umbilical morphology, and thick, parietal callus of *P.* (*E.*) *diabloensis*. This specimen represents the first occurrence of this species outside of California, where *P.* (*E.*) *diabloensis* is reported in rocks of middle (?) and late Miocene age. As noted by Marincovich (1977, p. 269), the species is best considered an exclusively upper Miocene one, because its middle Miocene record is based on a single occurrence and requires verification by further collecting.

This species is similar in morphology to three other species of *Euspira* known in Alaskan Tertiary faunas: *P.* (*E.*) *lincolnensis* (Weaver, 1916), *P.* (*E.*) *ramonensis* (Clark, 1918), and *P.* (*E.*) *pallidus* (Broderip and Sowerby, 1829). *Polinices lincolnensis* occurs in upper Eocene to middle Miocene strata of the Pacific Northwest, and in lower to middle Miocene strata of central California. In Alaska the species has been tentatively recognized in the Narrow Cape Formation of Sitkinak Island (Text-fig. 1) in the western Gulf of Alaska (Allison and Marincovich, 1981), which contains a Juanian (late Oligocene or earliest Miocene) molluscan fauna, and in the Oligocene Stepovak Formation on the Alaska Peninsula (UA specimens). *Polinices diabloensis* differs from *P. lincolnensis* by its larger size, more elevated spire, more strongly impressed suture, thinner parietal callus, and thinner inner lip-umbilical callus (Marincovich, 1977, p. 268). The umbilicus of *P. lincolnensis* is usually more broadly open than in *P. diabloensis*, and some specimens of the former species show a distinct swelling at the midpoint of the umbilical callus. *Polinices ramonensis* differs from *P. diabloensis* by being much smaller (14 mm is an average height for the former species), by having a slitlike umbilicus, and by having a relatively thinner parietal callus. *Polinices ramonensis* is known in upper Oligocene and lower Miocene strata of the Poul Creek Formation in the Yakataga district (Clark, 1932) and in the Juanian fauna of the Narrow Cape Formation of Sitkinak Island (Allison and Marincovich, 1981), as well as in upper Oligocene and lower Miocene beds of California and Washington (Marincovich, 1977, p. 269). It has been common in North Pacific faunas since the Pliocene. *Polinices pallidus*, discussed below, differs from *P. diabloensis* by its distinctly lower spire, relatively smaller umbilical opening, its usually more slender inner lip and, in larger adults, by its much thinner parietal callus (Marincovich, 1977, p. 269).

Polinices diabloensis is a distinctly North American faunal element that aids in correlating the Tachilni Formation with strata in California.

Type information.—Holotype: UCMP, No. 11595. Type locality: Walnut Creek, Contra Costa County, northern California; San Pablo Formation; upper Miocene.

Tachilni Formation occurrence.—USGS locality M7140 (1 adult)

Figured specimen.—USNM 339817.

Stratigraphic and geographic range.—The following information is from Marincovich (1977). This species is known only in middle (?) and upper Miocene strata. Middle (?) Miocene: Temblor (?) Formation, Calaveras Valley, Santa Clara County, northern California. Upper Miocene: Santa Margarita Formation, north Coalinga area, and Domengine Ranch quadrangle, central California; upper part of the San Pablo Formation, Contra Costa County, northern California; Neroly Formation, Contra Costa County, northern California.

Polinices (Euspira) pallidus
(Broderip and Sowerby, 1829)
Plate 22, figures 18, 23

Natica pallida Broderip and Sowerby, 1829, p. 372.
Polinices (*Euspira*) *pallida* (Broderip and Sowerby). Dall, 1921, p. 164, pl. 14, fig. 5; Oldroyd, 1927, vol. 2, pt. 3, p. 126, pl. 97, fig. 9.
Polinices pallidus (Broderip and Sowerby). MacGinitie, 1959, p. 91, pl. 12, fig. 10.
Polinices (*Euspira*) *pallidus* (Broderip and Sowerby). Marincovich, 1977, p. 278–281, pl. 25, figs. 1–6, 8 [contains extensive synonymy].

Discussion.—This naticid is recognized by its relatively elongate proportions, small umbilical opening, and a narrow umbilical callus that has a gentle central swelling. The parietal callus is characteristically thin, has a distinct anterior lobe, and moderately fills the posterior apertural angle (Marincovich, 1977). One Tachilni specimen (Pl. 22, fig. 18) is considered to be typical of *P.* (*E.*) *pallidus*, while two are only tentatively assigned to this species due to imperfect pres-

ervation. A fourth specimen (Pl. 22, fig. 23) placed in this species is remarkable for its large size and other atypical morphologic features.

The one unusually large Tachilni specimen is 55.8 mm high and 46.5 mm in diameter, compared to an average size for *P.* (*E.*) *pallidus* of 25 mm high and 20 mm in diameter. The largest specimen previously known is a Holocene individual from Bristol Bay, Alaska, 46.7 mm high and 41.8 mm in diameter (Marincovich, 1977, p. 279). The large Tachilni specimen is further atypical in having a parietal callus that is relatively thicker than usual for the species and more heavily fills the posterior apertural angle. However, in the most important morphologic features, those of the umbilical area, this specimen is typical of *P.* (*E.*) *pallidus*. The occurrence of this large specimen in the Tachilni fauna is anomalous in that it contradicts the observation of Marincovich (1977, p. 281) that fossils of *P.* (*E.*) *pallidus* are much smaller than living specimens. The very large size and parietal callus thickness of this specimen are not considered to have taxonomic importance.

A comparison between *P.* (*E.*) *pallidus* and the other Tachilni species of *Euspira*, *P.* (*E.*) *diabloensis* (Clark, 1915), is made in the discussion of the latter species.

Polinices (*Euspira*) *pallidus* first appeared in middle Miocene faunas of southern California and the Yakataga Formation, Yakataga district, Alaska, became common across the North Pacific margin during the Pliocene, and has remained abundant in high-latitude North Pacific, Arctic, and North Atlantic faunas to modern times (Marincovich, 1977). There are no undoubted Tertiary occurrences of *P.* (*E.*) *pallidus* in Asia. Reports from the Pliocene of east-central Honshu (Yokoyama, 1920, p. 77) and the Miocene of Okinawa (MacNeil, 1960, p. 57) appear to be based on other naticid species.

In modern seas, *P.* (*E.*) *pallidus* clearly prefers cold-water habitats, but its possible presence in Miocene warm-water faunas of central and southern California (Marincovich, 1977) suggests that the species may have had a broader thermal tolerance in the Tertiary than it does today.

Type information.—Holotype: unknown and presumably in BM(NH). Type locality: Icy Cape, Chukchi Sea coast, northwestern Alaska; Holocene.

Tachilni Formation occurrence.—USGS localities M7139 (1 adult), M7143 (2 adults, as "cf."), M5163 (1 adult); UA locality A-169 (1 adult).

Figured specimens.—USNM 339818; UA 2492.

Stratigraphic and geographic range.—The following information is from Marincovich (1977), except as noted. The species ranges from the middle Miocene to Holocene. Middle Miocene: Kern River area, southern California. Middle Miocene to Pliocene: Yakataga Formation, Yakataga district, Alaska. Upper Miocene: Etchegoin Formation, Coalinga area, central California. Upper Pliocene or lower Pleistocene: Tugidak Formation, Tugidak Island, Trinity Islands, western Gulf of Alaska; Rio Dell Formation, Humboldt County, northwestern California (Roth, 1979). Pliocene or Pleistocene: Tjörnes sequence, *Serripes* and *Mactra* groups, Iceland. Lower Pleistocene: unnamed beds at Moonstone Beach, Humboldt County, northwestern California (Roth, 1979); Santa Barbara Formation of Smith (1912), Santa Barbara, southern California. Lower and upper Pleistocene: Gubik Formation, Arctic coastal plain, northern Alaska (USGS coll.). Upper Pleistocene: Elk River and Port Orford Formations, Cape Blanco area, southwestern Oregon (Kennedy, 1978; Roth, 1979); terrace deposits at Point Año Nuevo, northern California (Kennedy, 1978). Holocene: Circumarctic, south to the U.S.–Mexican border in the eastern Pacific; to Japan in the western Pacific; to North Carolina in the western Atlantic; to the North Sea and Portugal in the eastern Atlantic (new southern range end-point, herein, based on one specimen from "coast of Portugal, 1430 m" depth, loaned to me by Rosina Fechter, Zoologische Staatssammlung Muenchen, West Germany). Reported in depths from 15 to 4,794 m, this species may occur intertidally too.

Genus **BULBUS** Brown *in* Smith, 1839
Bulbus fragilis (Leach, 1819)
Plate 22, figure 20

Natica fragilis Leach, 1819, p. 62.
Bulbus fragilis (Leach). Marincovich, 1977, p. 335–338, pl. 31, figs. 4–7 [contains extensive synonymy].

Discussion.—The shell of this species is very thin and the distinctive umbilical callus is a thin, narrowly semicircular wash that nearly conceals a slitlike umbilicus at its base. Because the one Tachilni specimen is somewhat crushed, the spire appears to be lower and the suture more deeply impressed than usual for this species. The parietal callus of the Tachilni specimen is nearly imperceptible, a common feature in *B. fragilis*. The minute spiral costellae typical of this species are not well-preserved, though their presence is suggested on some parts of the shell.

Bulbus fragilis is known in the Tachilni fauna by a single specimen that is the first Miocene occurrence of this species. An extensive synonymy and discussion of this species is given in Marincovich (1977).

Bulbus fragilis is a distinctly cool-water element in the Tachilni fauna, because its modern range includes only the Arctic, North Pacific, and North Atlantic Oceans. It has been reported on sand and mud bottoms in depths of 37 to 317 m in the northeastern Pacific and in depths to 600 m in the northern Atlantic (Marincovich, 1977).

Type information.—Holotype: location unknown (Marincovich, 1977). Type locality: Baffin Bay, between Greenland and Canada; Holocene.

Tachilni Formation occurrence.—USGS locality M7143 (1 young adult).

Figured specimen.—USNM 339819.

Stratigraphic and geographic range.—The Tachilni specimen is the oldest one known. The following range information is taken from Marincovich (1977): Upper Pliocene: Beringian marine transgression, Kivalina, western Alaska. Middle Pleistocene: Kotzebuan marine transgression, type section, Baldwin Peninsula, Kotzebue Sound, Alaska. Undifferentiated Pleistocene: Scotland, Iceland, and possibly England and northern U.S.S.R. This species is present in several USGS collections from the Pleistocene Gubik Formation, northern Alaska. Holocene: circumarctic. In the eastern Pacific, south to Atka and Unalaska Islands, Aleutian Islands, and the Shumagin Islands; in the western Pacific, south to Iwate Prefecture, northwest Honshu, Japan; in the western Atlantic, south to Massachusetts Bay; in the eastern Atlantic, south to the Lofoten Islands, Norway.

Genus **NATICA** Scopoli, 1777

Subgenus **CRYPTONATICA** Dall, 1892

Natica (Cryptonatica) clausa Broderip and Sowerby, 1829

Plate 22, figure 21

Natica clausa Broderip and Sowerby, 1829, p. 372.

Natica (*Cryptonatica*) *clausa* Broderip and Sowerby. Arnold, 1903, p. 313–314, pl. 10, fig. 13; Dall, 1921, p. 163, pl. 14, fig. 11; MacNeil, 1957, p. C109, pl. 13, figs. 12, 13, pl. 15, fig. 19; Marincovich, 1977, p. 410–418, pl. 41, figs. 7–10, pl. 42, figs. 1–6 [contains extensive synonymy].

Discussion.—This well-known species is among the most common Tachilni gastropods and is the most abundant naticid in Alaskan marine Tertiary strata. It is easily recognized by its globose shell with low to moderately elevated spire, completely closed umbilicus, and smooth, semicircular umbilical callus. Its calcareous operculum is rarely fossilized.

In high-latitude North Pacific faunas of late Cenozoic age *N.* (*C.*) *clausa* is most similar to *N.* (*C.*) *oregonensis* (Conrad, 1865), a middle Miocene to early Pliocene species of Oregon and Washington, and to *Natica* (*Tectonatica*) *janthostoma* Deshayes, 1839, a Miocene to Holocene species. The former species differs from *N.* (*C.*) *clausa* by having a more elevated spire and from the latter species differs by having an open umbilicus. A discussion of *N.* (*C.*) *clausa* and its many synonyms is given in Marincovich (1977).

The oldest published occurrence of this species is in the late Oligocene or earliest Miocene (*i.e.*, Juanian) fauna of the Narrow Cape Formation on Sitkinak Island, western Gulf of Alaska (Allison and Marincovich, 1981). The species also occurs in probable lower Miocene strata in the upper part of the Poul Creek Formation in the Yakataga district, Alaska (Clark, 1932; Marincovich, 1977). It is common in middle Miocene to Holocene faunas from Japan to California.

This circumarctic species is a cool-water indicator. Even though *N.* (*C.*) *clausa* lives as far south as Japan and southern California, it does so by dwelling in cool water at progressively greater depths southward. Modern specimens are found in depths as shallow as nine m in northern Alaska, but no shallower than about 150 m off of southern California (Marincovich, 1977, p. 418).

Type information.—Holotype: unknown. Type locality: unknown.

Tachilni Formation occurrence.—USGS localities M7139 (1 adult, 2 juveniles), M7146 (3 adults, as "cf."), M7201 (1 adult), M7203 (1 adult); UA localities A-169 (1 adult), A-170 (1 adult), A-301 (abundant at outcrop); CAS locality 60279 (1 adult).

Figured specimen.—USNM 339820.

Stratigraphic and geographic range.—Numerous Miocene to Holocene occurrences for the northeastern Pacific are cited in Marincovich (1977). The oldest known specimens occur in the late Oligocene or earliest Miocene fauna of the Narrow Cape Formation, Sitkinak Island, western Gulf of Alaska (Allison and Marincovich, 1981). Northwestern Pacific fossil occurrences are not well documented, though the species is commonly cited in Neogene and Pleistocene faunas of northern Japan, Sakhalin and Kamchatka. The species is circumboreal in modern seas, living in the eastern Pacific south to San Diego, California (32°43′N); in the western Pacific, south to Japan and Korea; in the western Atlantic, south to Cape Hatteras, North Carolina; and, in the eastern Atlantic, south to Spain and perhaps the Mediterranean. Living specimens have been collected in depths from nine to 970 m on soft bottoms, in progressively greater depths from north to south (Marincovich, 1977).

Subgenus **TECTONATICA** Sacco, 1890

Natica (Tectonatica) janthostoma Deshayes, 1839
Plate 22, figure 22

Natica janthostoma Deshayes, 1839, p. 361.
Natica (Cryptonatica) janthostoma Deshayes. Dall, 1921, p. 164, pl. 14, fig. 12; Oldroyd, 1927, vol. 2, pt. 3, p. 123, pl. 97, fig. 5.
Natica (Tectonatica) janthostoma Deshayes. Marincovich, 1977, p. 405–408, pl. 40, figs. 10–13, pl. 41, figs. 2–5 [contains extensive synonymy].

Discussion.—This species is characterized by its well-developed semicircular umbilical callus, strong funicle, and relatively small umbilical opening posterior to the umbilical callus. The umbilicus is always open, in contrast to the otherwise similar *Natica (Cryptonatica) clausa* Broderip and Sowerby, 1829, in which the umbilicus is always closed by a semicircular callus. The illustrated Tachilni specimen, at 35 mm high, is slightly larger than previously known fossil specimens but much smaller than the largest Holocene individuals, which attain 61 mm in height (Marincovich, 1977).

Tachilni specimens of *N. (T.) janthostoma* constitute the first occurrence of this species in Alaska Tertiary strata. This species was previously known in Alaska only in Pleistocene faunas of the Gubik Formation in northern Alaska (USGS coll.). Outside of Alaska, this species has been reliably reported as a fossil only in Neogene and Pleistocene faunas of the western U.S. and Canada. Addicott (1976a, p. 105) noted its lowest occurrence in Washington and Oregon in Wishkahan faunas. As noted by Marincovich (1977, p. 407), earlier reports of *N. (T.) janthostoma* as a late Tertiary and Quaternary fossil in Japan are based on the related species *N. (T.) janthostomoides* (Kuroda and Habe, 1949). The main differences between these two species are that *N. (T.) janthostomoides* has a narrower umbilical callus, so that the umbilicus is open along most of the callus margin instead of only at its posterior end, and has an umbilical sulcus relatively much smaller than in *N. (T.) janthostoma*. In addition, the operculum of *N. (T.) janthostomoides* has two shallow grooves near its outer margin, whereas the operculum of *N. (T.) janthostoma* is virtually smooth.

Natica (Tectonatica) janthostoma is an extralimital element in the Tachilni fauna, because it currently lives only in the northwestern Pacific, as noted below. Its modern bathymetric range is unknown.

Type information.—Holotype: unknown. Type locality: Kamchatka, U.S.S.R.; Holocene.

Tachilni Formation occurrence.—USGS locality M7150 (1 adult); UA locality A-301 (2 adults).

Figured specimen.—UA 2493.

Stratigraphic and geographic range.—The following information is largely from Marincovich (1977), except as noted. The species ranges from lower upper Miocene to Holocene. Lower upper Miocene (Wishkahan): Skonun Formation, Queen Charlotte Islands, British Columbia, Canada (Addicott, 1978); Empire Formation, Coos Bay, Oregon. Upper upper Miocene (Graysian): upper part of Montesano Formation, southwestern Washington. Upper (?) Pliocene: Montesano Formation of Weaver (1912), southwestern Washington. Middle Pliocene or Pleistocene: Merced Formation, Sonoma County, northwestern California. Middle Pleistocene: Elk River Formation, southwestern Oregon. Holocene: Kamchatka to Hokkaido, and Vladivostok, U.S.S.R. Reported from Korea by Habe (1950).

Family **CYMATIIDAE** Iredale, 1913

Genus **FUSITRITON** Cossmann, 1903

Fusitriton oregonensis (Redfield, 1846)
Plate 23, figure 1

Triton oregonense Redfield, 1846, p. 163–168, pl. 11, figs. 2a, b.
Argobuccinum (Fusitriton) oregonensis (Redfield). Oldroyd, 1927, vol. 2, pt. 2, p. 242–243, pl. 37, figs. 1–3.
Fusitriton oregonensis (Redfield). Smith, 1970, p. 485–497, pl. 45, figs. 1–11, pl. 46, figs. 1, 2, 5, 6, 8, 13, 14, pl. 47, figs. 2, 3 [contains extensive synonymy].

Discussion.—This well-known North Pacific species is represented in the Tachilni fauna by a single incomplete specimen that has well-preserved sculpture but lacks an aperture and anterior canal. Axial sculpture consists of coarse, unevenly spaced ribs and one weakly developed varix per whorl. Inconspicuous incremental growth lines also are present. The main spiral sculpture is of low, flat-topped costae that bear minute, weakly developed and closely spaced costellae. The spiral interspaces are less than one-third the width of the costae, except for the anteriormost preserved interspace, which is about three-fourths the width of adjacent costae. Two or three thread-like costellae of varied width are present in each interspace.

The spiral sculpture of *F. oregonensis* is variable within broad limits, as thoroughly documented by Smith (1970). In general, however, typical specimens of *F. oregonensis* have relatively fine spiral costae that are bifurcate, and lack the faint spiral grooves of the Tachilni specimen that give the latter a more coarsely sculptured appearance. Specimens similar in sculptural coarseness to the Tachilni one were reported by Smith (1970, p. 503–504, pl. 46, figs. 3, 4) from presumed Miocene deposits at Cape Yakataga and Middleton Island, Alaska, and were referred to "*Fusitriton* sp.? aff. *F. oregonensis*." Smith (1970, p. 504)

noted an absence of varices on the Cape Yakataga and Middleton Island specimens she examined, whereas weakly developed varices are present on the Tachilni specimen. Ariey (1978, p. 133–134) also referred to specimens of *Fusitriton* from the Cape Yakataga area using Smith's (1970) identification. Specimens illustrated by Smith (1970) and Ariey (1978) differ from the Tachilni individual by having bifurcate spiral costae.

Smith's (1970) citation of a Miocene age for Middleton Island specimens of "*Fusitriton* sp.? aff. *F. oregonensis*" from the Yakataga Formation is erroneous. More recent paleomagnetic and molluscan faunal studies (Plafker and Addicott, 1976, p. 1, 23; Allison, 1978, p. 182) indicate an early Pleistocene age for the Yakataga Formation on Middleton Island, and no older rocks crop out there. Smith (1970) was also uncertain whether her specimens from Cape Yakataga (Text-fig. 1) came from the Yakataga or underlying Poul Creek Formation, due to inadequate locality information on museum specimen labels. Ariey (1978, p. 133–134) made extensive collections of mollusks from both formations at Cape Yakataga and found "*Fusitriton* sp.? aff. *F. oregonensis*" only in the Yakataga Formation. Her citation of this taxon in the Poul Creek Formation at Cape Yakataga, based on the reported occurrence there of "*Fusitriton* aff. *F. matthewsonii* (Gabb) and *F. vancouverense* (Clark and Arnold)" by MacNeil (*in* Miller, 1971, p. 4), is in error because *Mediargo matthewsonii* (Gabb, 1866) [including *Bursa vancouverensis* Clark and Arnold, 1923, as a junior synonym] is not considered to be synonymous with *F. oregonensis* by Smith (1970) or later workers. Further, extensive USGS collections of Poul Creek mollusks contain no specimens that may be identified as *F. oregonensis*. Thus, the oldest known Alaskan occurrence of *F. oregonensis* is in the stratigraphically highest Newportian fauna and a Wishkahan fauna in the lower part of the Yakataga Formation at Cape Yakataga (Ariey, 1978), in beds of middle and late Miocene age. Outside of the Yakataga district, *F. oregonensis* has been found in Alaska only in the Topsy Formation of the Lituya district in the eastern Gulf of Alaska (Marincovich, 1980, p. C12–C13). The Topsy fauna is of Newportian age and roughly coeval with Yakataga Formation faunas from which the oldest specimens of *F. oregonensis* at Cape Yakataga are known.

Smith's (1970, p. 492) report of *F. oregonensis* in Japanese Miocene faunas requires verification, because Masuda and Noda (1976) cited only Pliocene occurrences in Japan. There seems to be no mention of this species in the Russian literature on Tertiary mollusks of Sakhalin, Kamchatka and adjacent areas.

"*Fusitriton* sp.? aff. *F. oregonensis*" of Smith (1970, p. 503–504, pl. 46, figs. 3, 4) is considered here to be a variant of *F. oregonensis*. The presence of coarse axial ribs, bifurcate spiral costae separated by narrow interspaces bearing one to three costellae, and overall shell form and size clearly ally the variant noted by Smith (1970) with *F. oregonensis*. The absence of varices on the one individual of "*Fusitriton* sp.? aff. *F. oregonensis*" illustrated by her, from Pleistocene beds on Middleton Island, may be peculiar to that individual because all Middleton Island Pleistocene specimens I examined in USGS collections have distinct varices, though they vary in strength among individuals. The Tachilni specimen differs from Smith's (1970) variant of *F. oregonensis* only by having spiral costae that are not bifurcate but that do bear minute, weakly developed spiral costellae. However, as Smith (1970, p. 489) noted for *F. oregonensis*, "Spiral microsculpture is variable between and within whorls of different individuals and is not a reliable specific character." This view is reinforced by USGS specimens from the Cape Yakataga area, in which some spiral costae are bifurcate but most are not. Smith (oral commun., 1981) does not object to considering "*Fusitriton* sp.? aff. *F. oregonensis*" as a coarsely costate variety of *F. oregonensis*.

In the modern North Pacific, *F. oregonensis* occurs in temperate to cold waters from central Honshu, Japan, to southern California (Smith, 1970). The species is known in depths as great as 2,370 m, but has been observed in the intertidal zone from Puget Sound, Washington, to southeastern Alaska (Smith, 1970, p. 491). Southwest from the Bering Sea and south of Puget Sound, it lives in progressively greater depths, evidently showing its preference for cooler waters (Smith, 1970) and also occurs on seamounts in the Gulf of Alaska (Somerton, 1981). The species has been collected in temperatures of 7–11°C in Puget Sound and in waters less than 8°C off southern California (Valentine and Emerson, 1961).

Type information.—Holotype: lost (Smith, 1970, p. 489). Type locality: Straits of Juan de Fuca, Washington; Holocene.

Tachilni Formation occurrence.—USGS locality M7139 (1 adult).

Figured specimen.—USNM 339821.

Stratigraphic and geographic range.—This species is reported in upper lower (?) or middle Miocene to Holocene faunas. Upper lower (?) or middle Miocene (Newportian Stage): Topsy Formation, Lituya district, eastern Gulf of Alaska (Marincovich, 1980). Lower middle Miocene (Newportian Stage): Yakataga Formation, Cape Yakataga and adjacent area, Yakataga

district, northeastern Gulf of Alaska (Smith, 1970; MacNeil *in* Miller, 1971; Ariey, 1978). Lower upper Miocene (Wishkahan Stage): Empire Formation, Coos Bay, Oregon (Dall, 1909). Smith (1970, p. 492–493) listed questionable Miocene occurrences in Japan, and gave numerous Pliocene and Pleistocene occurrences in North Pacific faunas extending from central Honshu, Japan, to southern California. Masuda and Noda (1976) cited only Pliocene records in Japan. Holocene: from central Honshu (south to Niigata in the Japan Sea and south to Cape Inubo on the Pacific Coast) and Hokkaido, Japan, to southern Kamchatka, the Aleutian and Pribilof Islands (south of the line of floating winter ice), the Gulf of Alaska, and south along the Pacific Coast of North America to San Nicolas Island, southern California (Smith, 1970).

Family **BUCCINIDAE** Rafinesque, 1815

Genus **BUCCINUM** Linnaeus, 1758

Buccinum cf. **B. planeticum** Dall, 1919
Plate 23, figures 2–4

Buccinum planeticum Dall, 1919, p. 326; Dall, 1925, p. 8, pl. 5, fig. 1; Oldroyd, 1927, vol. 2, pt. 1, p. 246–247, pl. 24, fig. 1; Kosuge, 1972, pl. 22, fig. 8.

Discussion.—Specimens assigned to this taxon consist of about six evenly rounded whorls that bear fine, closely spaced spiral costellae and coarse, irregularly spaced axial folds. Spiral costellae are separated by slightly narrower interspaces that each bear a medial thread. Axial folds are most strongly developed on early whorls and become progressively obsolete on adult whorls. In some instances, the axial folds do not extend onto the anteriormost portion of a whorl. All Tachilni specimens consist of incomplete molds and casts. Several individuals are 50 mm or more in height and probably exceeded 60 mm high when intact.

Tachilni specimens match well the original description of this species, except that they lack the spiral costellae occurring as "fasciculate bands of five or six threads" (Dall 1919, p. 326). Tachilni specimens do not show this grouping of spiral costellae, and it also is not shown in illustrations of the holotype of *B. planeticum* (Dall, 1925, pl. 5, fig. 1; Kosuge, 1972, pl. 22, fig. 8). The holotype of *B. planeticum* is 65 mm high and 35 mm in diameter (Dall, 1919), which is similar in size to Tachilni specimens. Illustrations of the holotype show a distinct flexure of the outer lip at the shoulder that is not evident on earlier whorls. Evidence of a similar flexure is shown on two of the best-preserved Tachilni specimens (Pl. 23, fig. 3).

Off western North America *Buccinum* is said to live in depths of 10 to 2,930 m (Keen and Coan, 1974).

Type information.—Holotype: USNM 223098. Type locality: USFC station 3305, in 42 m depth southwest of Hagemeister Island, Bristol Bay, southeastern Bering Sea; bottom temperature 5.5°C (Dall, 1919).

Tachilni Formation occurrence.—USGS localities M7146 (4 adults), M7150 (9 adults), M7256 (4 adults), M7258 (1 adult); UA locality A-301 (4 adults, 2 juveniles; abundant at outcrop).

Figured specimens.—USNM 339822; UA 2494.

Stratigraphic and geographic range.—This species has not been reported previously as a fossil. It was reported to be common in the eastern Bering Sea from Nunivak Island to Bristol Bay by Dall (1919, p. 326), who later gave a range from the Pribilof Islands, Bering Sea, Alaska to the Queen Charlotte Islands, British Columbia, Canada (Dall, 1921, p. 99).

Genus **MOLOPOPHORUS** Gabb, 1869

Molopophorus cf. **M. bogachielii** (Reagan, 1909)
Plate 23, figures 5–7

Buccinum bogachielii Reagan, 1909, p. 218, pl. 5, figs. 51a, b.
Molopophorus bogachieli [sic] (Reagan). Addicott, 1976a, p. 105, 110, pl. 3, fig. 13; Addicott, 1978, p. 680, 682, figs. 5c–e.

Discussion.—Although *M. bogachielii* has not been cited often in literature it is an important index species in Oregon and Washington, where it occurs only in Wishkahan and Graysian faunas (Addicott, 1976a). The shell is elongate, with an elevated spire and short anterior canal. There are fine, closely spaced axial folds on early whorls (Addicott, 1976a, 1978), but these appear to decline progressively in relief during ontogeny, so that none occurs on the adult body whorl. Two obscure, widely spaced spiral costellae occur on each whorl (Reagan, 1909), but are missing from the relatively poorly preserved Tachilni specimens. Two such spiral costellae are present on the penultimate whorl of a specimen figured by Addicott (1976a, pl. 3, fig. 13), but are not clearly shown on three other individuals figured later by him (Addicott, 1978, figs. 5c–5e). Four columellar folds are present on Tachilni specimens. The two anterior folds are very slender and set closely together, and the two posterior folds are wider and set farther apart. Because this species is known from few specimens, its range of morphologic variation has not been defined. One variable aspect of shell form appears to be the apical angle. A Pacific Northwest Wishkahan specimen illustrated by Addicott (1976a) has an apical angle of 47°, whereas specimens from the Wishkahan Skonun Formation in British Columbia have apical angles of 45°, 53°, and 56° (Addicott, 1978). The two Tachilni specimens have apical angles of 33° and 37°, and the more complete of these

has a clearly more elongate appearance than previously illustrated specimens of *M. bogachielii*. For this reason my identification of the Tachilni specimens is tentative.

The two line drawings accompanying the original description of *M. bogachielii* show only the body whorl and incomplete penultimate whorl of the type specimen. Two obscure spiral costellae are visible on the body whorl, but not on the penultimate whorl, and no axial sculpture or columellar folds were figured or described by Reagan (1909). My present concept of this species therefore is based on illustrations published by Addicott (1976a, 1978), which show specimens more complete and better preserved than the holotype. Even though several Tertiary species of *Molopophorus* are known from California, Oregon and Washington (Weaver, 1942; Keen and Bentson, 1944), none is easily confused with *M. bogachielii* as used by Addicott (1976a, 1978). Five Tertiary species of *Molopophorus* have been described from Japan (Masuda and Noda, 1976, p. 229), but they are not extremely close in form or sculpture to *M. bogachielii*. The single Russian reference to a Tertiary species of *Molopophorus* (Zhidkova, 1972, p. 66, pl. 15, fig. 3) cites "*Molopophorus* cf. *anglonana* (Anderson)," a Miocene species of California and Washington (Weaver, 1942, p. 470–471), in the Miocene Okruglovska Formation of the Kuril Islands. Unfortunately, Zhidkova's (1972) illustration shows a very poorly preserved specimen whose generic assignment is doubtful.

The only previous report of *Molopophorus* in Alaska is a reference to *M. matthewi* Etherington, 1931, a Newportian index species (Addicott, 1976a), at an unspecified locality in the lower part of the Yakataga Formation in the Cape Yakataga area (Plafker and Addicott, 1976, p. 21). This species was not later noted in the Yakataga Formation by Ariey (1978) or Addicott, Winkler, and Plafker (1978), so its presence in Alaska needs verification.

The presence of tentatively identified *M. bogachielii* in the Tachilni fauna is an important faunal tie to the Pacific Northwest, where the species is known only in the Wishkahan and Graysian Stages (Addicott, 1976a, p. 105, 110).

Type information.—Holotype: USNM 328362. Type locality: USGS 10127, Olympic Peninsula, northwestern Washington; Quillayute Formation; lower upper Miocene.

Tachilni Formation occurrence.—USGS locality M7150 (2 adults, as "?"); UA localities A-170 (1 adult), A-301 (1 adult).

Figured specimens.—UA 2495, 2496.

Stratigraphic and geographic range.—This species is reportedly restricted in the Pacific Northwest to the Wishkahan Stage (lower upper Miocene) and the Graysian Stage (upper upper Miocene). Wishkahan: Skonun Formation, Queen Charlotte Islands, British Columbia, Canada (Addicott, 1978); Empire Formation, southwestern Oregon (Roth, 1979). Probable Wishkahan (Addicott, 1976a): Quillayute Formation, northwestern Washington (Reagan, 1909). Graysian: upper part of the Montesano Formation, southwestern Washington (Addicott, 1976a).

Family **NEPTUNEIDAE** Roeding, 1798

Genus **BERINGIUS** Dall, 1886

Beringius hertleini MacNeil, 1970
Plate 23, figure 13

Beringius hertleini MacNeil, 1970, p. 72–74, figs. 4, 5; Marincovich *in* Detterman, Yount, and Case, 1981, sheet 2 [as "?"].

Discussion.—*Beringius hertleini* is characterized by its large size, large siphonal fasciole, subsutural tabulation, and well-developed spiral costae on all whorls. Spiral costae are well-developed but subdued and separated by interspaces of about equal or greater width. Interspaces of the earlier whorls rarely bear costellae, but spiral costellae are numerous on the final one-half of the body whorl of some large individuals. Axial growth lines are visible on all whorls and are fine except on the final one-fourth body whorl on large individuals, where growth lines are more conspicuous and may be greatly thickened and raised. On some shells, including the holotype (MacNeil, 1970, fig. 5), axial growth lines behind the aperture largely conceal the spiral costae.

This species is one of several large, Neogene neptuneids known from the Alaska Peninsula. The only such species equal in size to *B. hertleini*, however, is *Tyrannoberingius rex* Marincovich, 1981a, which was described from the Unga Conglomerate Member of the Bear Lake Formation at Cape Aliaksin (Text-fig. 2). Although *T. rex* also has a prominent siphonal fasciole, the shell differs from *B. hertleini* by lacking spiral costae and having axial growth lines that become progressively coarser during ontogeny and have a very coarse, ropelike texture on the final one-fourth of the body whorl. The tabulate subsutural area of *B. hertleini* is missing from *T. rex*, and the suture of *B. hertleini* is appressed rather than narrowly channeled as in the latter species. The largest known specimen of *B. hertleini* is 160 mm long and the largest known specimen of *T. rex* is 170 mm long (Marincovich, 1981a, p. 178).

Other species of *Beringius* reported from the Unga Conglomerate at Cape Aliaksin are *B. hataii* MacNeil,

1973, and *B.* aff. *B. crebricostatus* (Dall, 1877). *Beringius hataii* is known only from fragmentary material and attains perhaps half the maximum length of *B. hertleini*, but the two species share predominately spiral sculpture. The spiral costae of *B. hataii* are more strongly raised than those of *B. hertleini*, however, and are separated by interspaces that are half or less the width of the costae. The spiral interspaces of *B. hertleini* are of diverse widths, but generally are as wide as or wider than the costae. *Beringius crebricostatus* is characterized by having coarse spiral costae that stand out in strong relief and are T-shaped in section. Except for fine incremental growth lines, axial sculpture is lacking. The largest Alaskan Tertiary examples of this species in USGS collections are about 75 mm in length. The Unga Conglomerate specimen referred to *Beringius* cf. *B. crebricostatus* by MacNeil (1973) appears to be more elongate and to have more subdued spiral costae than typical individuals of *B. crebricostatus*, but it does seem to have the T-shaped costae that are unique among North Pacific gastropods.

Beringius hertleini is known to occur only in the Tachilni Formation at Cape Tachilni and in the nearby South Walrus Peak stratigraphic section. However, unidentifiable fragments of a large gastropod that may be this species occur in several USGS collections from the Bear Lake Formation.

Modern species of *Beringius* of western North America are cited in depths of 35 to 600 m by Keen and Coan (1974).

Type information.—Holotype: USNM 646463. Type locality: USGS M4044, "upper ledge of the beach cliff at Cape Tachilni" (MacNeil, 1970, p. 69), Alaska Peninsula, Alaska; Tachilni Formation; upper Miocene.

Tachilni Formation occurrence.—USGS localities M4044 (4 adults, 2 juveniles), M5163 (1 juvenile), M7140 (1 adult), M7146 (1 adult), M7150 (1 fragment, as "?"); UA localities A-169 (2 adults), A-170 (1 adult), A-301 (fragments, as "?"); CAS localities 60278 (2 adults), 60279 (5 adults).

Figured specimen.—UA 2498.

Stratigraphic and geographic range.—This species is reliably reported only in the Tachilni Formation at Cape Tachilni and adjacent areas. It has been questionably cited in middle or upper Miocene strata of the unnamed upper member of the Bear Lake Formation (Marincovich *in* Detterman, Yount, and Case, 1981) that crop out near Black Peak, Alaska Peninsula (Text-fig. 2).

Genus **NEPTUNEA** Roeding, 1798

Subgenus **NEPTUNEA** Roeding, 1798

Neptunea (Neptunea) lyrata altispira Gabb, 1869
Plate 23, figure 8

Neptunea altispira Gabb, 1869, p. 44–45, pl. 14, fig. 2; Stewart, 1927, p. 395, pl. 31, fig. 6.

Neptunea (*Neptunea*) *lyrata altispira* Gabb. Nelson, 1974, p. 111–118, pl. 2, figs. 3, 5, pl. 3, figs. 1–7, pl. 4, figs. 1–6, pl. 5, figs. 1–7, pl. 6, figs. 1–5 [contains extensive synonymy]; Nelson, 1978, p. 209, figs. 6–8.

Discussion.—This subspecies of *Neptunea* is characterized by relatively coarse primary spiral costae separated by slightly narrower interspaces. The better preserved of the two confidently identified Tachilni specimens, a juvenile, bears a single thin costella in each interspace. More fully developed adults contain third-order spiral elements in interspaces on the penultimate and body whorls (Nelson, 1974, p. 113). There is a broad, sloping, slightly concave subsutural area that contains obscure spiral lines. Axial sculpture consists only of growth lines that produce a rugose shell surface as they intersect the spiral costellae. This subspecies has a wide range of sculptural variation, which has been extensively described and illustrated by Nelson (1974).

This extinct taxon occurs widely in North Pacific late Cenozoic cold-water faunas. Its southernmost occurrence in the eastern Pacific is in Pliocene or Pleistocene strata of northwestern California, and in the western Pacific it occurs as far south as Chiba Prefecture, east-central Honshu, Japan, in Pliocene deposits (Nelson, 1974, p. 116–118). However, *N.* (*N.*) *lyrata altispira* is most common in Neogene and Pleistocene rocks rimming the Gulf of Alaska, although the ages of its occurrences there are not precisely known. The oldest known specimens occur in the Yakataga Formation of the northeastern Gulf of Alaska (Nelson, 1974, p. 118), in rocks thought to be of latest middle or earliest late Miocene age (Nelson, 1978, p. 209). This subspecies, along with the rest of the *N.* (*N.*) *lyrata* (Gmelin, 1791) stock, remained in Alaskan waters during the Miocene and early Pliocene before expanding southward and northward (Nelson, 1974, 1978). The only previous identification of *N.* (*N.*) *lyrata altispira* in the Tachilni fauna was by Marincovich (*in* McLean, Englehardt, and Howell, 1978), and was based on the present specimens. This taxon is not known to occur elsewhere on the Alaska Peninsula, although it does occur in the upper Pliocene or Pleistocene Tugidak Formation of Tugidak Island, Trinity Islands, western Gulf of Alaska (Nelson, 1974, p. 117).

Based on its biogeographic history, *N.* (*N.*) *lyrata altispira* had a strong preference for cold-water habitats (Nelson, 1974, 1978). Its initial appearance, in the lower part of the Yakataga Formation, coincided with

the onset of glacial marine conditions in the northeastern Gulf of Alaska, and its later southward and northward migrations occurred during the relatively cold Pliocene and Pleistocene epochs (Nelson, 1974, 1978). Thus, this taxon is strong evidence for a cold-water element in the Tachilni fauna.

Type information.—Holotype: ANSP 4322. Type locality: Scotia section of the Wildcat Group, probably in the Rio Dell Formation, Humboldt County, northwestern California (Nelson, 1974, p. 116); upper Pliocene or lower Pleistocene (Roth, 1979).

Tachilni Formation occurrence.—USGS localities M4044 (1 adult), M7139 (3 adults, 1 juvenile), M7143 (2 adults, 1 juvenile).

Figured specimen.—USNM 339823.

Stratigraphic and geographic range.—This subspecies is known to range from the upper middle Miocene or lower upper Miocene to lower or middle Pleistocene. Occurrences cited are those given by Nelson (1974), with exceptions noted. Upper middle or lower upper Miocene to lower Pleistocene: Yakataga Formation of Yakataga, Malaspina, and Lituya districts, and Middleton Island, northeastern Gulf of Alaska. Pliocene: Iioka Formation of Chiba Prefecture, Kubo Formation of Iwate Prefecture, and Hamada Formation of Aomori Prefecture, northeastern Honshu, Japan. Upper Pliocene or lower Pleistocene: Tugidak Formation, Tugidak Island, Trinity Islands, western Gulf of Alaska; Rio Dell Formation, Scotia, Humboldt County, northwestern California (Nelson, 1974; Roth, 1979). Lower Pleistocene: Yakataga Formation, Middleton Island, northeastern Gulf of Alaska. Lower or middle Pleistocene: Port Orford Formation of Baldwin (1964), Curry County, southern Oregon (Nelson, 1974; Roth, 1979).

Neptunea (Neptunea) sp. D aff. **N. (N.) modesta** (Kuroda *in* Homma, 1931), of Nelson, 1974
Plate 23, figures 9, 10

Neptunea (*Neptunea*) sp. D aff. *N.* (*N.*) *modesta* (Kuroda *in* Homma, 1931). Nelson, 1974, p. 201, pl. 32, figs. 3, 4.

Discussion.—This Tachilni taxon is characterized by fine spiral costae that are separated by much wider interspaces occupied by well-developed primary and secondary costellae. The interspaces are three to four times the width of the spiral costae, and each contains a central primary costella that has two to six secondary costellae on each side of it. The subtabulate, slightly concave subsutural area is wider than the interspaces and also contains primary and secondary costellae. Axial sculpture consists only of incremental growth lines.

Compared to the other Tachilni species of *Neptunea*, *N.* (*N.*) *lyrata altispira* Gabb, 1869, the present species has relatively much finer spiral costae, much wider interspaces, and finer primary costellae. Many individuals of *N.* (*N.*) *lyrata altispira* illustrated by Nelson (1974, 1978) have several costellae per interspace, unlike the illustrated single-costellate Tachilni specimens, but their costellae appear to be coarser and less numerous than in *N.* (*N.*) sp. D aff. *N.* (*N.*) *modesta*.

This species has been reported previously only on the Alaska Peninsula, in the Tachilni Formation at Cape Tachilni, and at an unidentified "upper Miocene or lower Pliocene" locality (Nelson, 1974). *Neptunea* (*Neptunea*) *modesta* has been recognized in the Bear Lake Formation near Port Moller, Alaska Peninsula (Nelson, 1974, p. 201), in rocks of presumed middle or late Miocene age.

Type information.—No name has been proposed for this taxon since first recognized by Nelson (1974).

Tachilni Formation occurrence.—USGS localities M3591 (1 adult), M5163 (1 juvenile), M7139 (2 adults, 1 juvenile), M7140 (2 adults), M7146 (1 adult), M7150 (2 adults); UA localities A-169 (3 adults), A-170 (1 adult, 1 juvenile).

Figured specimen.—USNM 339824.

Stratigraphic and geographic range.—Known only in the Tachilni fauna.

Subgenus **GOLIKOVIA** Habe and Sato, 1972

Neptunea (Golikovia) plafkeri Kanno, 1971
Plate 23, figures 16, 17

Neptunea (*Neptunea*) *plafkeri* Kanno, 1971, p. 115–116, pl. 14, figs. 1–3.

Neptunea (*Golikovia*) *plafkeri* Kanno. Nelson, 1974, p. 387–390, pl. 63, fig. 7, pl. 64, figs. 3, 6, 7; Nelson, 1978, p. 208.

Discussion.—One nearly intact adult of this species represents the first verified presence of *N.* (*G.*) *plafkeri* in the western Gulf of Alaska. The Tachilni specimen is 68.9 mm high and 42.4 mm in diameter, with five whorls (protoconch missing) and a nearly complete apertural margin. All whorls have a narrow concavity just below the suture, and the body whorl has a subtabulate shoulder. Spiral sculpture is lacking and axial sculpture is of growth lines, some of which are weakly raised. The body whorl is proportionately more inflated than earlier whorls.

As noted by Nelson (1974, p. 388), this species is most closely related, and perhaps ancestral, to *N.* (*G.*) *smirnia* (Dall, 1919), a Pliocene to Holocene species of the northeastern Pacific. Individuals in some fossil populations are difficult to assign to one species or the

other, though *N.* (*G.*) *smirnia* commonly has a more elevated and slender spire, a more weakly developed subtabulate shoulder on the body whorl, and less concave subsutural whorl profiles on the early adult whorls (Nelson, 1974).

This species has been confidently identified by Nelson (1974) only in the lower part of the Yakataga Formation in the northeastern Gulf of Alaska, although he tentatively assigned a body whorl from the Miocene Bear Lake Formation near Port Heiden, Alaska Peninsula (Text-fig. 2), to *N.* (*G.*) *plafkeri* (Nelson, 1974, p. 390). This species also has been questionably identified in the Newportian fauna of the Topsy Formation of the Lituya district, eastern Gulf of Alaska, in strata coeval with the lower part of the Yakataga Formation (Marincovich, 1980, p. C12). Ariey (1978, p. 142) reported *N.* (*G.*) *plafkeri* was present in the lower half of the type Yakataga Formation, including the lowermost beds, at Cape Yakataga, but was absent from the underlying Poul Creek Formation. However, she did report this species from five localities in the Poul Creek Formation, but not in the Yakataga Formation, in her Lare Glacier stratigraphic section about 35 km east of Cape Yakataga (Text-fig. 1). If her species identification and formational assignment are correct, Ariey's (1978) Lare Glacier specimens are the first individuals of *N.* (*G.*) *plafkeri* from a pre-Newportian fauna. However, because Ariey (1978, p. 39–40) observed that the Poul Creek-Yakataga formational boundary is "subtle" in the Lare Glacier section, her report of *N.* (*G.*) *plafkeri* in the Poul Creek fauna must be viewed with caution. Ariey's (1978) Poul Creek fauna at Lare Glacier is presumably of Pillarian (early Miocene) age. Finds of this species in other Poul Creek stratigraphic sections are needed to verify its presence so early in the Miocene.

Based on past studies (Kanno, 1971; Nelson, 1974; Ariey, 1978) and Yakataga Formation specimens in USGS collections, the probable highest occurrence of *N.* (*G.*) *plafkeri* is in Wishkahan faunas. More refined biostratigraphic studies may show that this species' range extends into the Graysian Stage (upper upper Miocene), but there is currently no evidence for this.

Type information.—Holotype: TUE, No. 10045. Type locality: TUE locality number 81104, dark gray, massive mudstone in lower part of Yakataga Formation along Poul Creek, Yakataga district, Alaska; lower or middle Miocene.

Tachilni Formation occurrence.—UA locality A-301 (1 adult).

Figured specimen.—UA 2499.

Stratigaphic and geographic range.—This uncommon species is reported to range from the lower (?) Miocene to lower upper (?) Miocene. Lower (?) Miocene (Pillarian?): Poul Creek Formation (?), Yakataga district, Alaska (Ariey, 1978). Upper lower or lower middle Miocene (Newportian): Topsy Formation, Lituya district, Alaska (Marincovich, 1980; questionable identification). Middle and(or) upper Miocene (Newportian and(or) Wishkahan): Yakataga Formation, Yakataga district (Kanno, 1971; Nelson, 1974; Ariey, 1978), and Lituya district (Nelson, 1974), Alaska; Bear Lake Formation near Port Heiden, Alaska Peninsula, Alaska (Nelson, 1974; tentative identification).

Family **CANCELLARIIDAE** Gray, 1853

Genus **CANCELLARIA** Lamarck, 1799

Cancellaria? species
Plate 23, figures 11, 12

Discussion.—A single imperfectly preserved specimen from UA locality A-301 consists of four whorls bearing axial and spiral sculpture. The body whorl has 15 curved axial costae that are best developed on the shoulder and become obsolete anteriorly. Eleven similar axial costae occur on the penultimate whorl, and remnants of axial costae are visible on all four preserved whorls. Spiral sculpture above the periphery on the body whorl consists of about seven costae separated by interspaces of about equal width that may each bear a costella. Sculpture below the periphery is less well preserved, but apparently consists only of spiral elements. Vestiges of spiral sculpture are seen on all preserved whorls. The aperture and inner lip are not well preserved. The specimen is 20.3 mm high and 17.6 mm in diameter.

The absence of visible columellar folds on the poorly preserved inner lip precludes certain assignment to *Cancellaria*. Assignment to *Buccinum* Linnaeus, 1758, is another possibility that would depend on collecting better-preserved specimens. However, species with similar whorl profiles and sculptural patterns from Tertiary faunas of Alaska (Kanno, 1971) and the Pacific Northwest (Weaver, 1942; Moore, 1963) have been assigned to *Cancellaria*.

In the northeastern Pacific, modern species of *Cancellaria* are found in depths of 25 to 550 m (Keen and Coan, 1974).

Tachilni Formation occurrence.—UA locality A-301 (1 specimen).

Figured specimen.—UA 2497.

Family **TURRIDAE** Swainson, 1840

Genus **OENOPOTA** Moerch, 1852

Oenopota cf. **O. candida** (Yokoyama, 1926)
Plate 23, figures 18–20

Bela candida Yokoyama, 1926, p. 261–262, pl. 34, figs. 1, 2.

Discussion.—*Oenopota candida* is a small species with about two nuclear and five adult whorls, a short anterior canal, and sculpture of coarse axial folds and very fine, closely spaced spiral costellae. Yokoyama (1926) reported a height of 13.6 mm and diameter of 6.0 mm for one specimen, observed 21 axial folds on the body whorl and 17 on the penultimate whorl, and noted that the shoulder normally has a rounded profile. He illustrated one specimen (Yokoyama, 1926, pl. 34, fig. 2) with a narrowly tabulate shoulder and referred to it as "var. *angulata*." Hatai and Nisiyama (1952, p. 173) recognized the tabulate morphotype as a full species.

Tachilni specimens assigned to *O.* cf. *O. candida* have rounded shoulder profiles, and the best preserved specimen (Pl. 23, figs. 18, 19) has 18 axial folds on its body whorl and 17 on its penultimate whorl. Remnants of fine, closely spaced spiral costellae occur on all Tachilni specimens, but this spiral sculpture is largely worn away. Four adult whorls only are preserved on the most complete specimen. The largest Tachilni specimen is 19.0 mm high by 11.1 mm in diameter, and the next smaller is 17.0 mm high and 10.6 mm in diameter, so both are larger than the single specimen cited by Yokoyama (1926). Differences in size and axial fold number, plus the relatively poor preservation of the Tachilni specimens makes their assignment to *O. candida* tentative. In addition, the large number of similar turrids described from North Pacific late Cenozoic faunas is reason enough to exercise caution in assigning names to species in this family.

As noted above, Yokoyama's (1926) type material contains two morphotypes, including specimens with a tabulate or rounded shoulder. This has led to varied interpretations of *O. candida* by subsequent workers, so that it is difficult to assess from the literature the formational occurrence of the species. Previous reports of *O. candida* are all from the northwestern Pacific, especially Japan, where the species is present in several formations usually assigned a Pliocene age (Hatai and Nisiyama, 1952; Masuda and Noda, 1976). Assignment of a lesser age to Tertiary epochal boundaries in recent years suggests a probable Miocene age for some formations in which *O. candida* occurs. Khomenko (1931, p. 100, pl. 12, figs. 20, 21) reported *O. candida* from inexactly described localities in the "upper Pliocene" Supranutovo Group (=Nutovo Formation of modern usage) of eastern Sakhalin, in strata that were later subdivided, renamed and assigned late Miocene and Pliocene ages (Menner, Baranova, and Zhidkova, 1977).

Type information.—Holotype: GT, number unknown (Hatai and Nisiyama, 1952). Type locality: "Sea cliff facing Mano bay, about 250 m [southeast] of the contact point of the two main roads near the primary school, Sawane-machi, Sado-gun (Sado Island)," Niigata Prefecture, west-central Honshu, Japan (Hatai and Nisiyama, 1952); Sawane Formation; Pliocene.

Tachilni Formation occurrence.—USGS localities M7143 (1 adult), M7146 (1 adult), M7150 (5 adults), M7256 (1 fragment, as "?").

Figured specimens.—USNM 339825, 339826.

Stratigraphic and geographic range.—This species has been reported only in Neogene strata of Honshu and Sakhalin. See discussion above.

Oenopota species A
Plate 23, figures 14, 15

Discussion.—A single individual of *Oenopota* differs from Tachilni specimens assigned to *O.* cf. *O. candida* (Yokoyama, 1926) by being distinctly more slender, smaller, and having a narrowly subtabulate shoulder. Remnants of relatively fine axial costae are present, but no spiral sculpture is preserved. Five whorls are present, with at least one nuclear whorl missing, and the specimen is 9.6 mm high and 4.7 mm in diameter. Preservation is not adequate for assigning even a tentative species name to this specimen.

Tachilni Formation occurrence.—USGS locality M7139 (1 adult).

Figured specimen.—USNM 339827.

APPENDIX

COLLECTING LOCALITIES

United States Geological Survey (USGS), Menlo Park, California

M309.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. Stream canyon along Pacific shore between Thinpoint Cove and Sandy Cove, 8.2 miles S 18° E of Frosty Peak, section 22, T 60 S, R 89 W. Coll. by H. H. Waldron, August 22, 1947.

M310.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. Beach cliff on Pacific shore between Thinpoint Cove and Sandy Cove, 6.5 miles S 38° E of Frosty Peak, sections 25 and 26, T 60 S, R 89 W. Coll. by H. H. Waldron, August 8, 1947.

M3588.—Alaska Peninsula, Alaska. Coll. by Standard Oil Company of California, 1965.

M4044.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. Upper ledge of beach cliff at Cape Tachilni, about 1,100 feet east and 300 feet north of southwest corner of section 36, T 60 S, R 90 W. Coll. by Standard Oil Company of California, 1968.

M4045.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. Base of beach cliff at Cape Tachilni, about 800 feet east and 100 feet south of the northwest corner of section 6, T 61 S, R 90 W. Coll. by Standard Oil Company of California, 1968.

M5163.—False Pass quadrangle, USGS 1:250,000, 1949 ed. Near

South Walrus Peak, 10,000 feet south and 36,100 feet east of latitude 55°N, longitude 163°W. Coll. by Union Oil Company, date unknown.

M5166.—False Pass quadrangle, USGS 1:250,000, 1949 ed. Near Cape Tachilni, 23,600 feet south and 26,800 feet east of latitude 55°N, longitude 163°W. Coll. by Union Oil Company, 1968.

M5167.—False Pass quadrangle, USGS 1:250,000, 1949 ed. 40,000 feet south and 31,600 feet west of latitude 55°N, longitude 163°W. Coll. by Union Oil Company, date unknown.

M5168.—Same location as M5166. Coll. by Union Oil Company, 1968.

M5169.—False Pass quadrangle, USGS 1:250,000, 1949 ed. 44,000 feet south and 34,800 feet west of latitude 55°N, longitude 163°W. Coll. by Union Oil Company, date unknown.

M5173.—Port Moller (D-1) quadrangle, USGS 1:63,360, 1963 ed. Within stratigraphic section extending from the northwest corner of section 34 to 1,000 ft east and 500 ft north of the southwest corner of section 27, T 48 S, R 69 W. Coll. by Union Oil Company, 1968.

M7139.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. Type locality of Tachilni Formation at Cape Tachilni, 49 meters above base of measured section, section 36, T 60 S, R 90 W; latitude 54°55′N, longitude 162°52′W. Coll. by Louie Marincovich, Jr., July 1977.

M7140.—Same location as M7139, but 2.4 meters higher in measured section. Coll. by Louie Marincovich, Jr., July 1977.

M7141.—Same location as M7139, but about 9 meters lower in measured section. Coll. by Louie Marincovich, Jr., July 1977.

M7142.—Same location as M7139, but 2 meters above base of measured section. Coll. by Louie Marincovich, Jr., July 1977.

M7143.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. South Walrus Peak stratigraphic section, 130 meters above base of measured section, section 19, T 60 S, R 89 W; latitude 54°57′N, longitude 162°50′W. Coll. by Louie Marincovich, Jr., July 1977.

M7144.—Same location as M7143, but 94 meters above base of measured section. Coll. by Louie Marincovich, Jr., July 1977.

M7145.—Same location as M7143, but 12 meters above base of measured section. Coll. by Louie Marincovich, Jr., July 1977.

M7146.—Same location as M7143, but 6 meters above base of measured section. Coll. by Louie Marincovich, Jr., July 1977.

M7149.—False Pass quadrangle, USGS 1:250,000, 1949 ed. Sea cliff exposure between False Pass and Morzhovoi Bay, 36 meters above base of Kenmore Head South stratigraphic section, latitude 54°51′41″N, longitude 164°38′42″W. Coll. by Louie Marincovich, Jr., July 1977.

M7150.—False Pass quadrangle, USGS 1:250,000, 1949 ed. Sea cliff exposure on north side of Ikatan Bay, about 3.3 kilometers west of Kenmore Head, latitude 54°53′47″N, longitude 164°40′43″W. Coll. by Louie Marincovich, Jr., July 1977.

M7200.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. Type locality of Tachilni Formation at Cape Tachilni, about 7 meters above base of measured section, section 35, T 60 S, R 90 W; latitude 54°55′N, longitude 162°52′W. Coll. by Irven Palmer, USGS, 1977.

M7201.—Same location as M7200, but about 42 meters above base of measured section. Coll. by Irven Palmer, USGS, 1977.

M7202.—Same location and stratigraphic position as M7139. Coll. by Irven Palmer, USGS, 1977.

M7203.—Same location as M7202, but 2.4 meters lower in measured section. Coll. by Irven Palmer, USGS, 1977.

M7204.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. Float specimens from type locality of Tachilni Formation at Cape Tachilni, section 35, T 60 S, R 90 W; latitude 54°55′N, longitude 162°52′W. Coll. by Irven Palmer, USGS, 1977.

M7256.—False Pass quadrangle, USGS 1:250,000, 1949 ed. Sea cliff exposure about 15 kilometers southwest of Kenmore Head, at an elevation of about 400 feet, section 30, T 61 S, R 92 W. Coll. by Hugh McLean, USGS, June 1977.

M7258.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. Float specimens from base of South Walrus Peak stratigraphic section, section 19, T 60 S, R 89 W; latitude 54°58′16″N, longitude 163°10′00″W. Coll. by Hugh McLean, USGS, June 1977.

California Academy of Sciences (CAS), San Francisco, California

60278.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. Promontory on shore just east of line between section 5 and section 6, T 61 S, R 90 W. Coll. by Mobil Oil Corporation, 1975.

60279.—Same locality data as CAS 60278.

60280.—Same locality data as CAS 60278.

University of Alaska (UA), Fairbanks, Alaska

A-169.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. About 100 yards upstream from beach, along a creek, slightly east of line between sections 5 and 6, T 61 S, R 90 W. Coll. by R. C. Allison, 1969.

A-170.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. In bluffs about 200–300 feet above beach level, along small creek, about 850 feet east of boundary line between sections 35 and 36, T 60 S, R 90 W. Coll. by R. C. Allison, 1969.

A-301.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. At base of low shoreline bluff, just north of second asterisk showing offshore rocks, section 24, T 60 S, R 89 W. Coll. by R. C. Allison, 1969.

A-302.—False Pass (D-3) quadrangle, USGS 1:63,360, 1963 ed. In shoreline bluff about 460 feet north and 1600 feet east of southwest corner of section 26, T 60 S, R 89 W. Coll. by R. C. Allison, 1969.

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PLATES

EXPLANATION OF PLATE 12

Figure — Page

1–4. ***Acila (Truncacila) empirensis*** Howe 78

1. Left valve of articulated valves, UA 2467; note obsolete radial sculpture near ventral margin; length 27.7 mm, height 22.0 mm, ×1.5; UA locality A-169.

2–4. Articulated valves, UA 2468; length 26.3 mm, height 22.1 mm, ×1.5; UA locality A-169.

2. Left valve.

3. Escutcheon, with slightly raised area in center.

4. Right valve.

5–7. ***Acila (Truncacila) ermani*** (Girard) 79

5. Left valve, USNM 265854; showing extremely weak radial sculpture; length 35.8 mm, height 28.0 mm, ×1; USGS locality M7140.

6. Central portion of left valve, USNM 265854 (see fig. 5); showing extremely weak radial sculpture and fine concentric growth lines; ×3.

7. Posterior portion of left valve, USNM 265854 (see fig. 5); showing coarser posterior sculpture; ×3.

8–9. ***Yoldia (Cnesterium) scissurata*** Dall 80

8. Right valve, UA 2469; showing oblique concentric sculpture; length 43.4 mm, height 22.3 mm, ×1; UA locality A-301.

9. Right valve, USNM 265855; with intact posterior end; length 52.4 mm, height 25.1 mm, ×1; USGS locality M7146.

10–17. ***Glycymeris grewingki*** Dall 81

10–11. Left valve, UA 2470; length 45.9 mm, height 45.9 mm, ×1; UA locality A-170.

10. Exterior, showing fine radial ribs.

11. Interior.

12. Hinge of left valve, UA 2471; length 32.9 mm, ×1; UA locality A-170.

13. Right valve, USNM 339752; length 39.0 mm, height 37.5 mm, ×1; USGS locality M7139.

14–15. Articulated valves, USNM 339753; length 43.8 mm, height 40.2 mm, thickness 19.3 mm, ×1; USGS locality M7139.

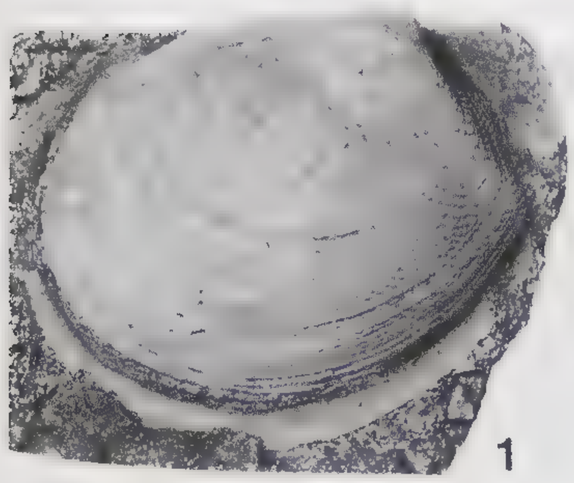
14. Dorsal view.

15. Left valve, showing fine radial sculpture.

16–17. Right valve, UA 2472; length 42.4 mm, height 37.1 mm, ×1; UA locality A-170.

16. Interior.

17. Exterior, showing fine radial sculpture.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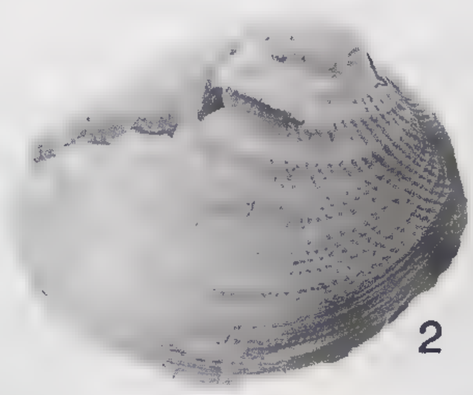
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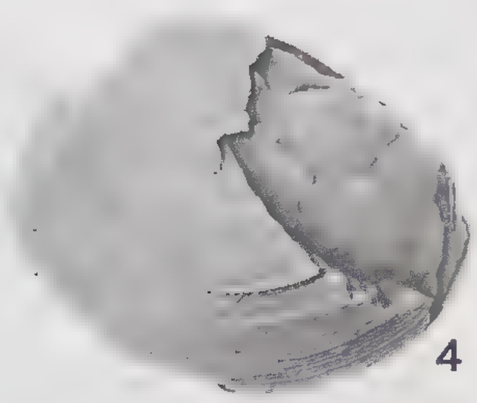
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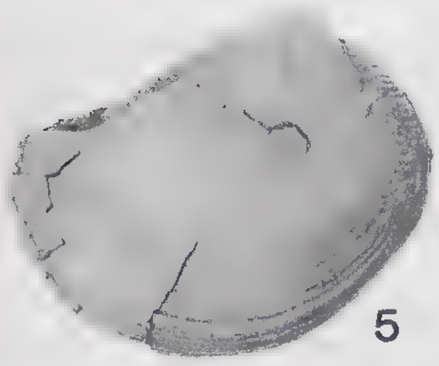
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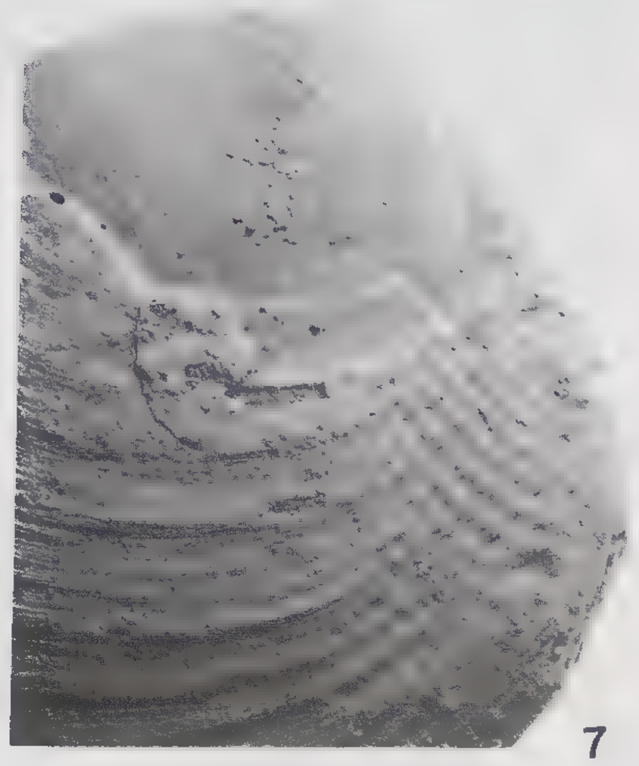
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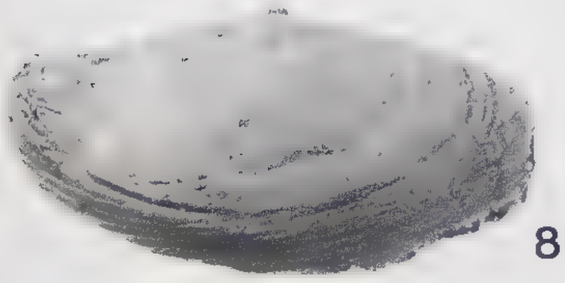
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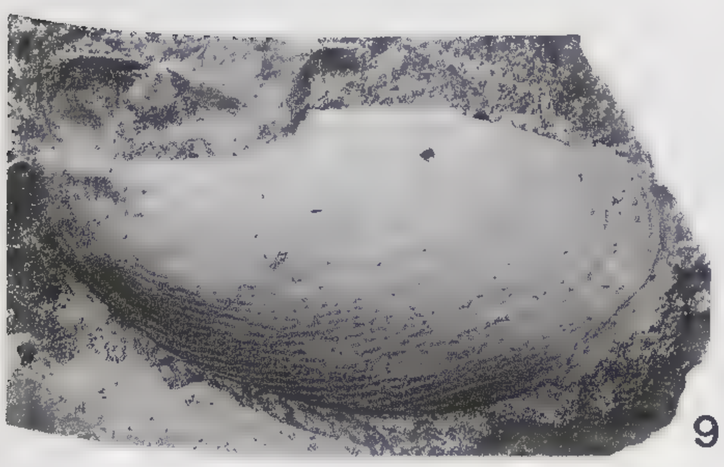
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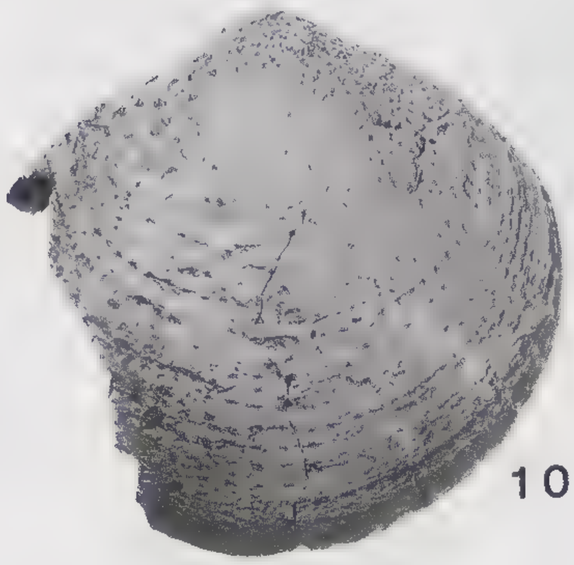
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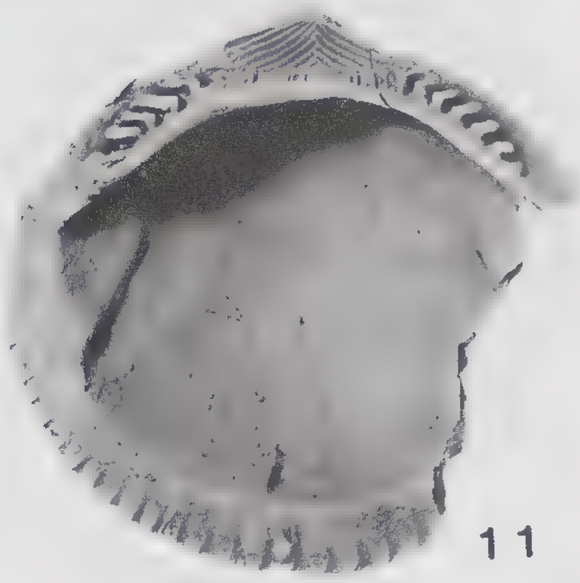
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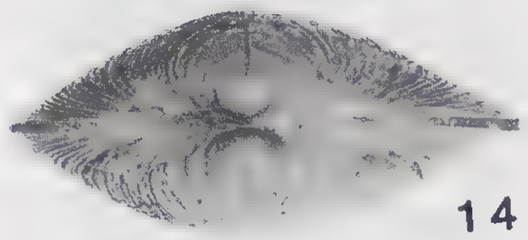
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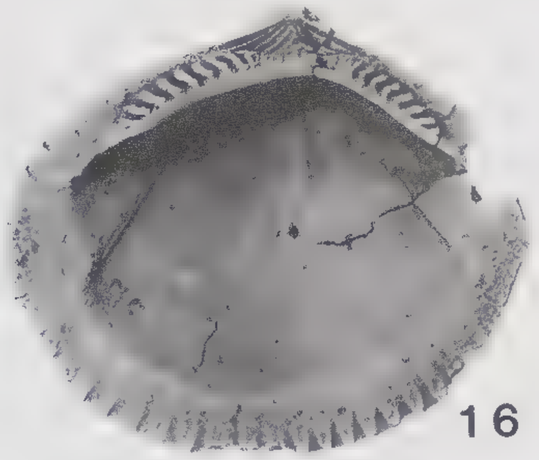
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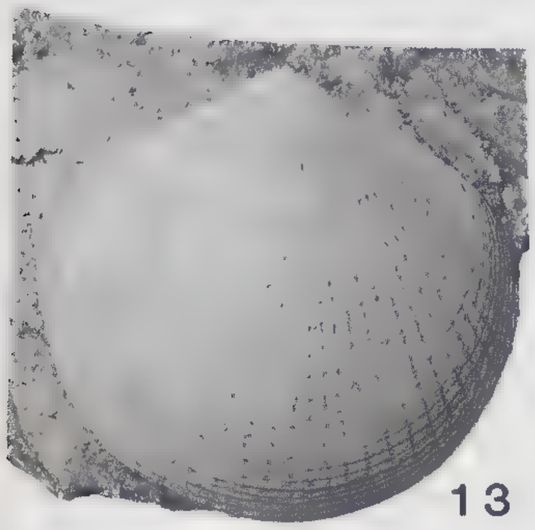
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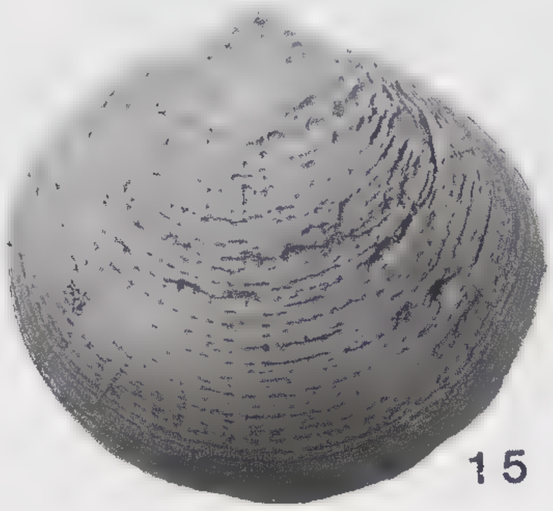
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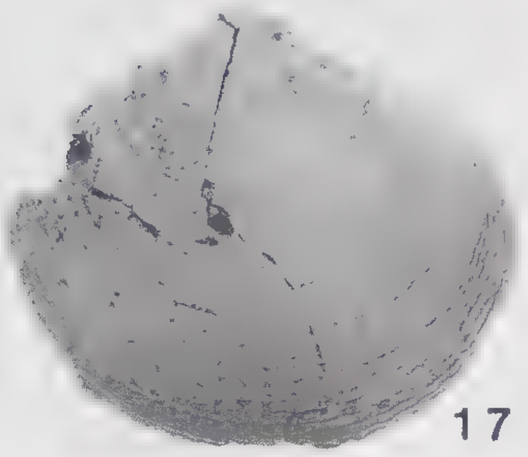
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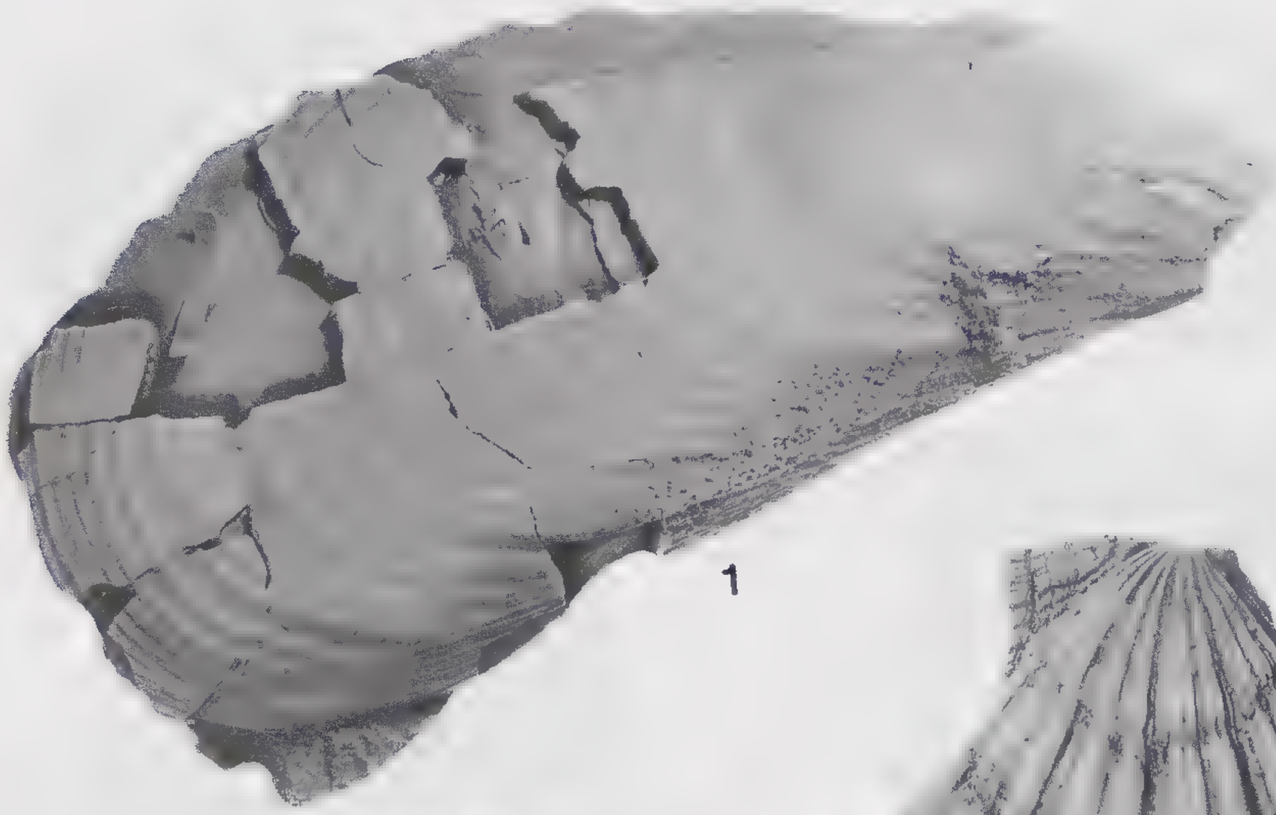

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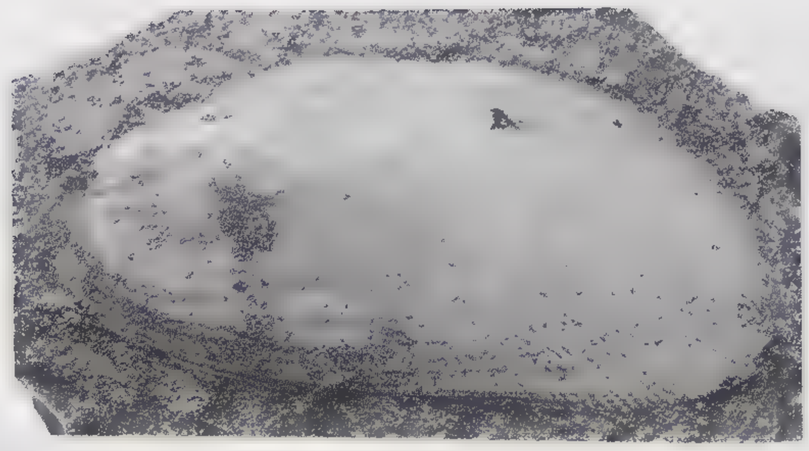

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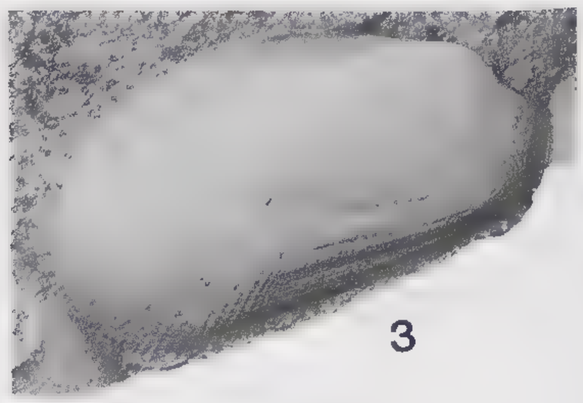

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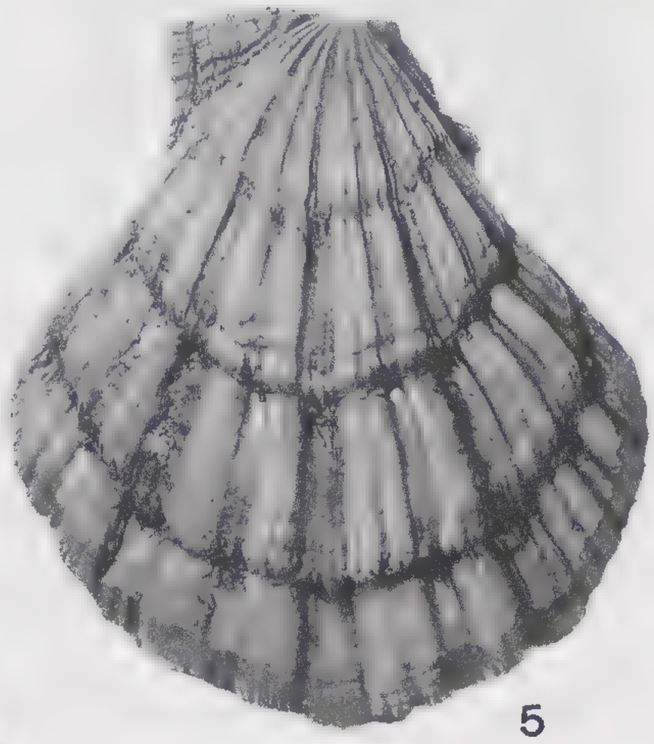

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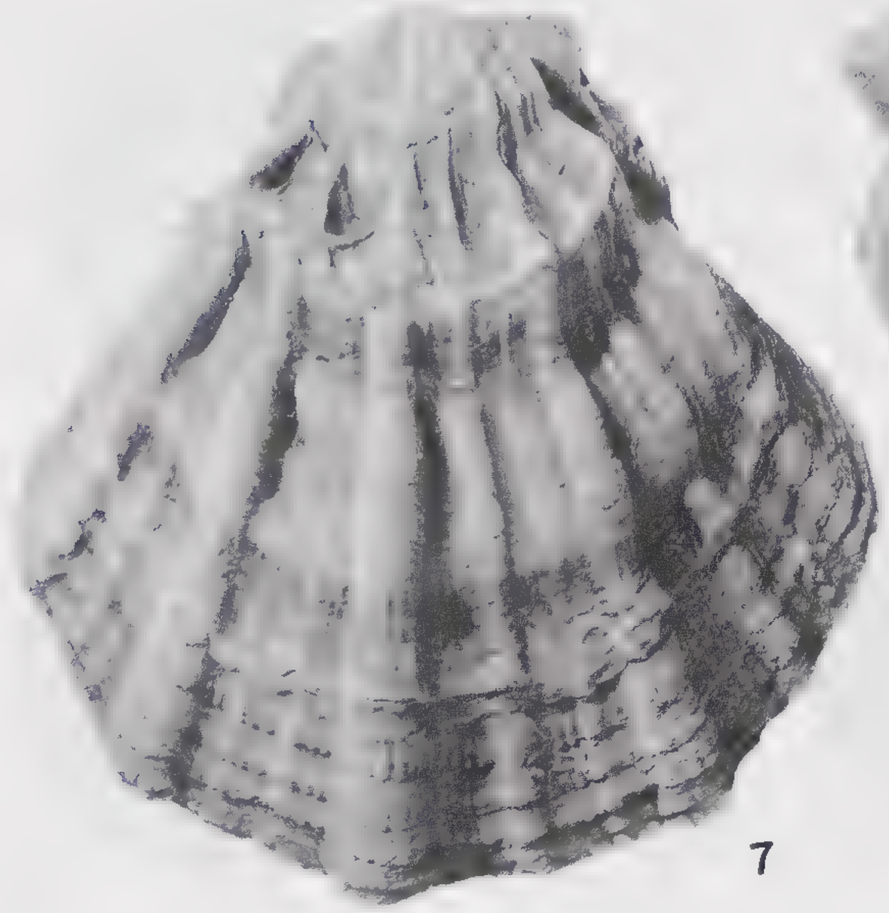

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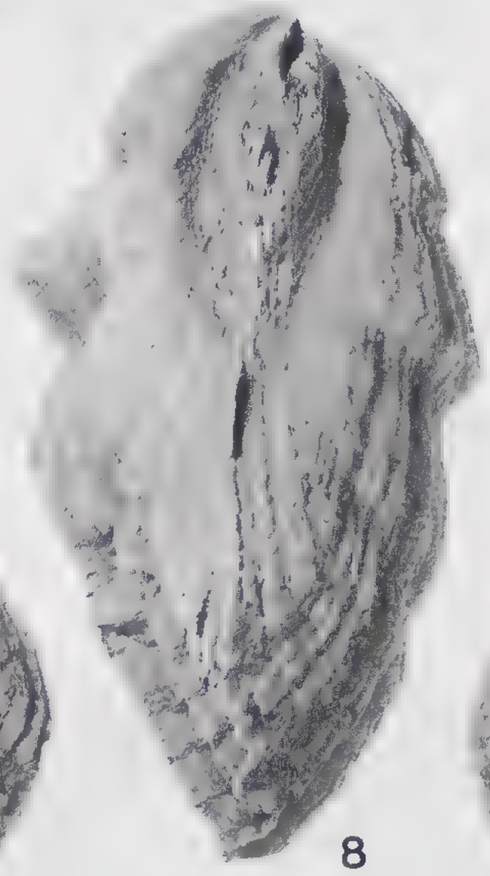

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EXPLANATION OF PLATE 13

Figure — Page

1. ***Crenomytilus coalingensis*** (Arnold) 82
   Right valve, USNM 339754; length 106.9 mm, height 48.5 mm, ×1; USGS locality M4045.

2–3. ***Musculus (Musculus) niger*** (Gray) 83

2. Left valve, USNM 339755; showing radial sculpture best-developed on posterior portion; length 60.5 mm, height 28.3 mm, ×1; USGS locality M7146.
3. Right valve, USNM 339756; showing well-developed posterior radial sculpture and weakly developed anterior radial sculpture; length 41.9 mm, height 23.1 mm, ×1; USGS locality M7146.

4–9. ***Chlamys (Swiftopecten) cosibensis cosibensis*** (Yokoyama) 84

4. Left valve, USNM 339757; length 70.5 mm, height 80.0 mm, ×1; USGS locality M7146.
5. Right valve, USNM 339758; showing well-developed step-like concentric sculpture; length 53.0 mm, height 60.9 mm, ×1; USGS locality M4044.
6. Left valve, USNM 339759; length 60.0 mm, height 65.0 mm, ×1; USGS locality M7146.

7–9. Articulated valves, UA 2473; length 71.5 mm, height 76.2 mm, thickness 39.7 mm, ×1; UA locality A-170.

7. Left valve.
8. Anterior view, showing high relief of concentric sculpture.
9. Right valve.

EXPLANATION OF PLATE 14

Figure — Page

1–2. ***Chlamys (Swiftopecten) cosibensis cosibensis*** (Yokoyama) 84
Left valve, USNM 339760; length 80.6 mm, height 93.5 mm, thickness 26.4 mm, ×1; USGS locality M7146.
1. Lateral view, showing well-developed radial and concentric sculpture.
2. Posterior view, showing high relief of sculpture.

3–8. ***Cyclocardia*** cf. ***C. roundiformis*** (Ilyina) 87
3–4. Articulated valves, UA 2474; length 17.2 mm, height 18.2 mm, ×1.5; UA locality A-170.
3. Left valve.
4. Right valve.
5. Right valve, USNM 339762; length 20.6 mm, height 21.1 mm, ×1; USGS locality M7146.
6. Right valve, UA 2500; length 19.6 mm, height 20.3 mm, ×1.5; UA locality A-170.
7–8. Articulated valves, USNM 339763; length 11.8 mm, height 10.5 mm, ×2; USGS locality M7139.
7. Left valve.
8. Right valve.

9–10. ***Cyclocardia*** species A 88
9. Right valve, UA 2475; showing coarse radial costae; length 30.8 mm, height 20.8 mm, ×1; UA locality A-169.
10. Dorsal view, UA 2475 (see fig. 9); showing articulation of valves; ×1.

11. ***Miodontiscus prolongatus*** (Carpenter) 88
Right valve, USNM 339765; length 6.2 mm, height 7.0 mm, ×2; USGS locality M7142.

12–14. ***Cyclocardia sakamotoi*** n. sp. 87
Articulated valves, USNM 339764 (holotype); length 34.0 mm, height 30.5 mm, thickness, 14.7 mm, ×1; USGS locality M7139.
12. Dorsal view.
13. Left valve.
14. Right valve.

15–17. ***Felaniella parilis*** (Conrad) 89
15–16. Articulated valves, UA 2476; length 16.4 mm, height 14.5 mm, thickness 6.1 mm, ×2; UA locality A-170.
15. Right valve.
16. Dorsal view.
17. Right valve, USNM 339766; length 22.8 mm, height 20.5 mm, ×1; USGS locality M7142.

18. ***Mizuhopecten mollerensis*** (MacNeil) 86
Fragment of right valve, USNM 339761; height 67.9 mm, ×1; USGS locality M7150.

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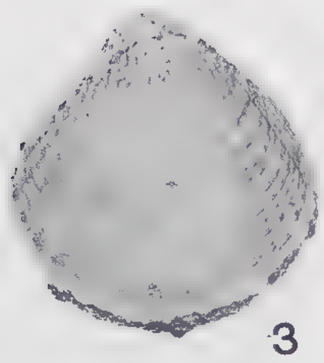
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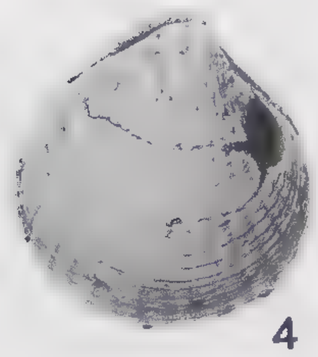
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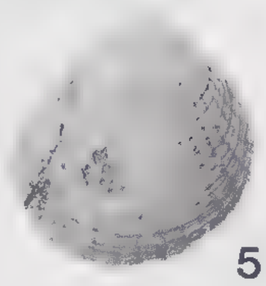
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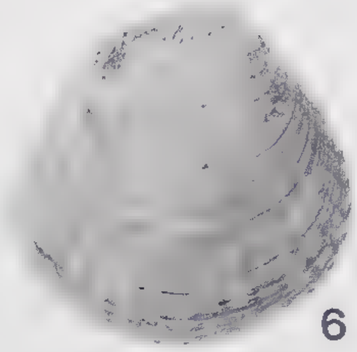
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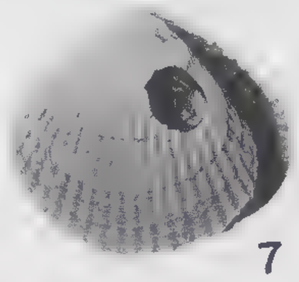
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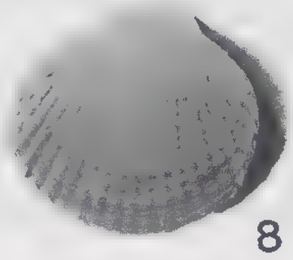
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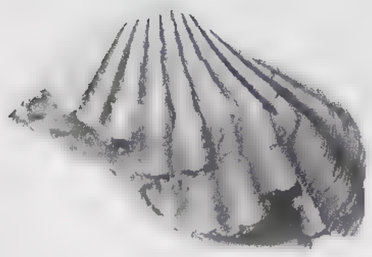
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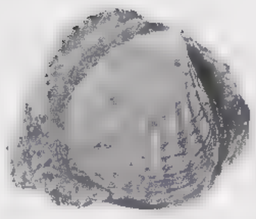
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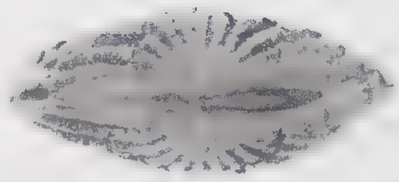
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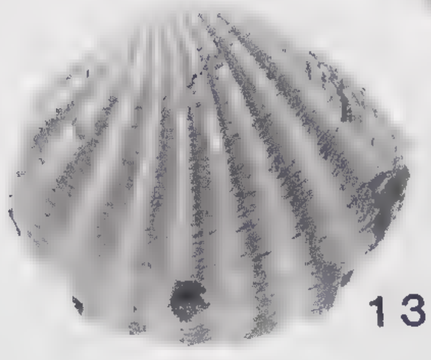
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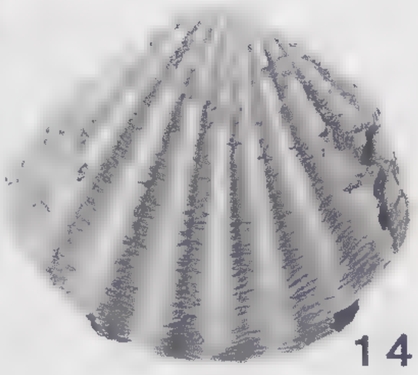
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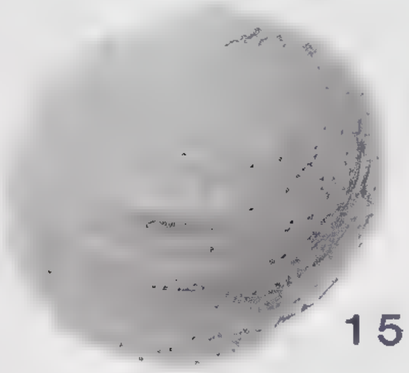
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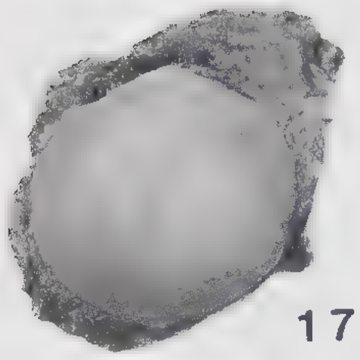
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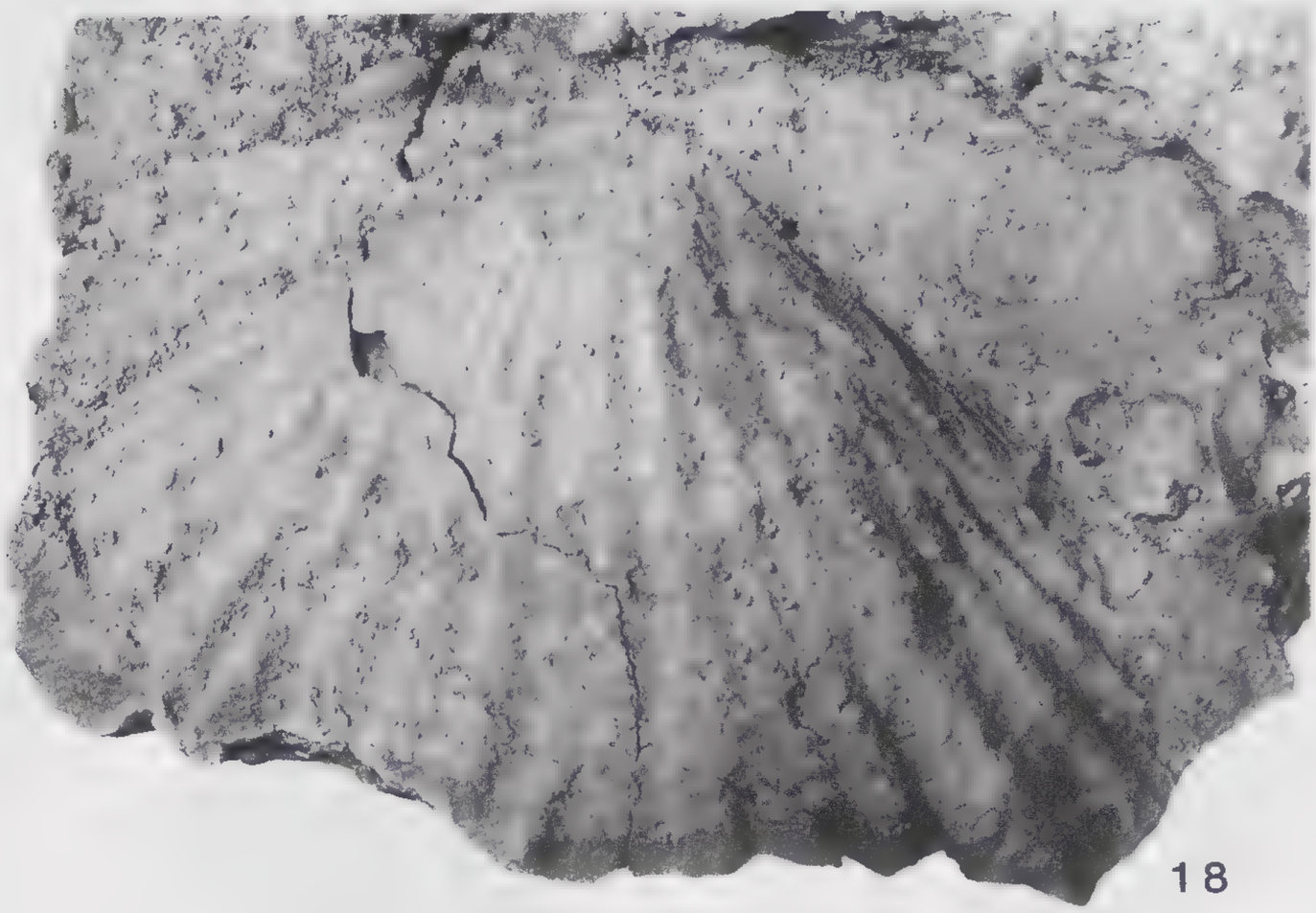
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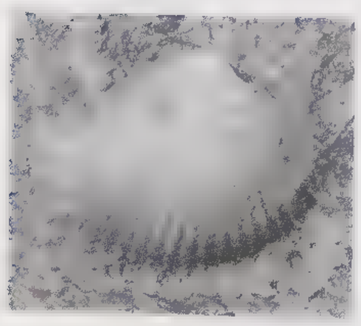
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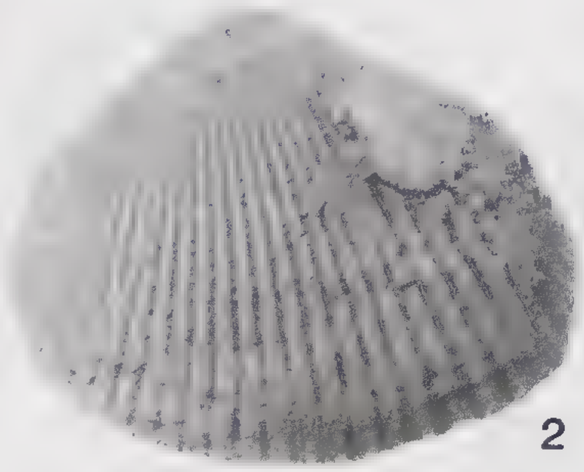
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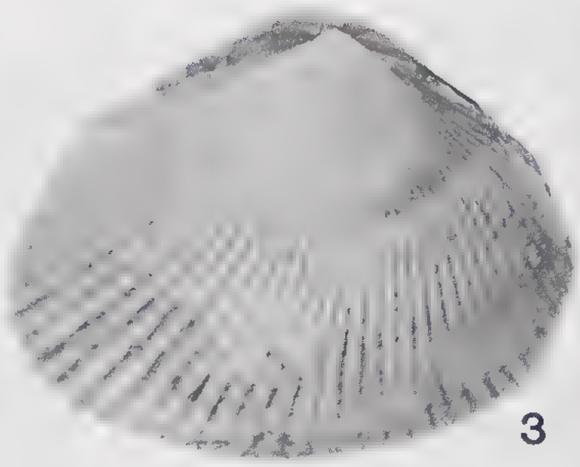
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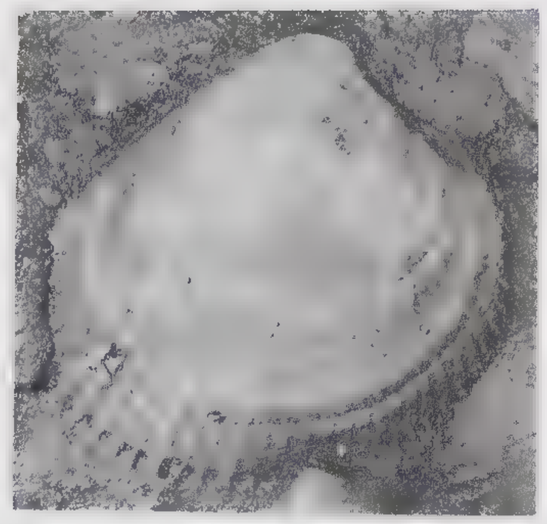
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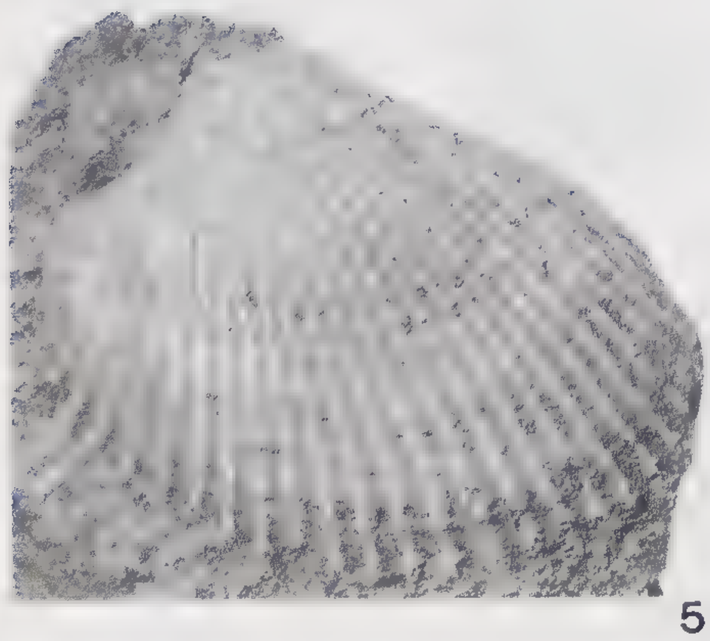
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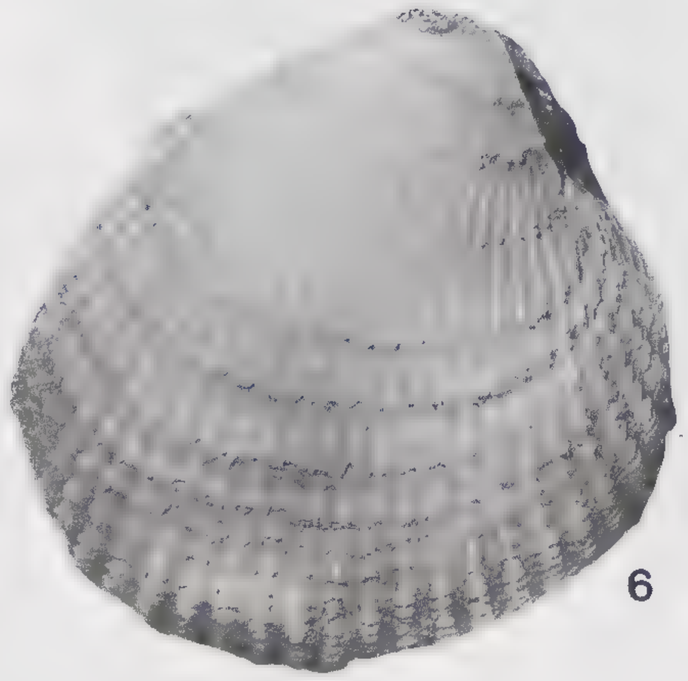
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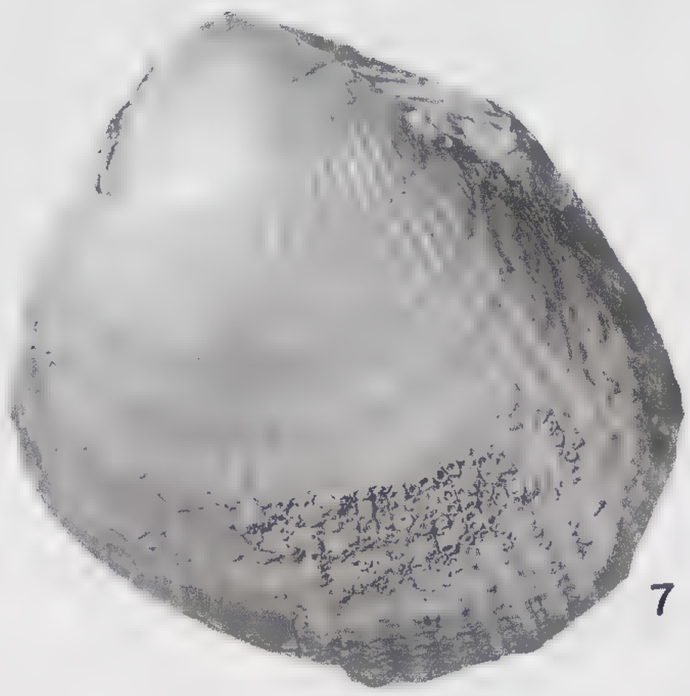
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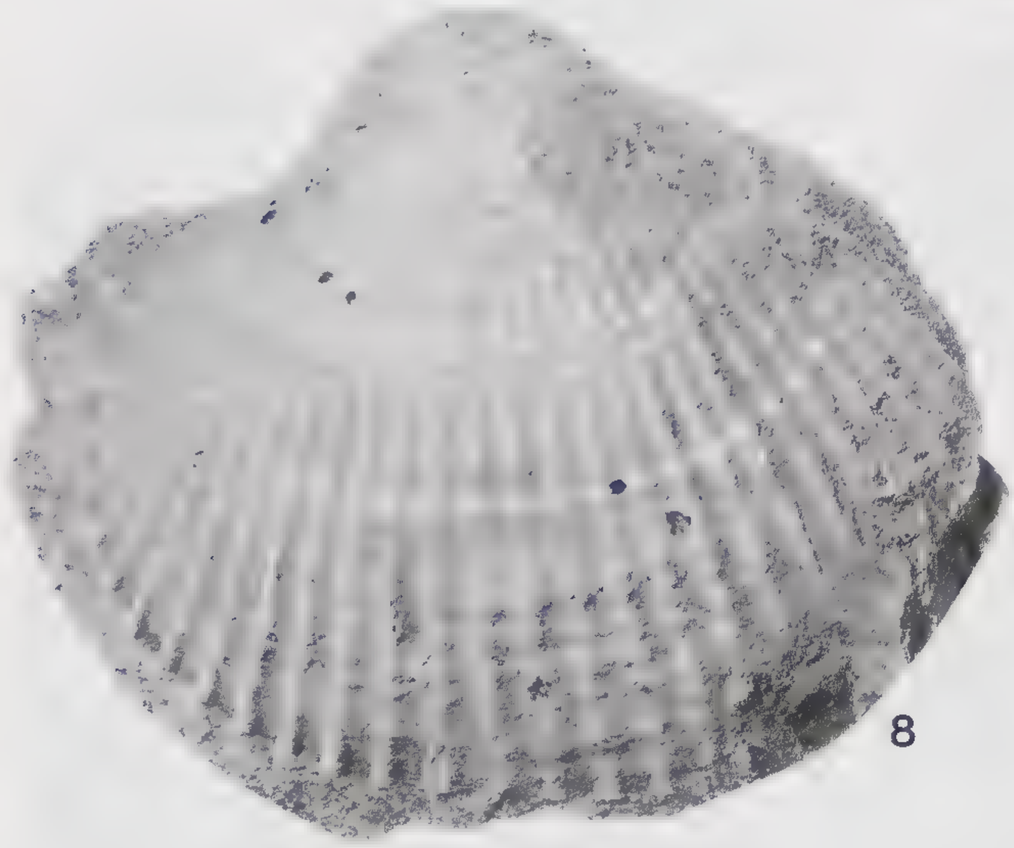
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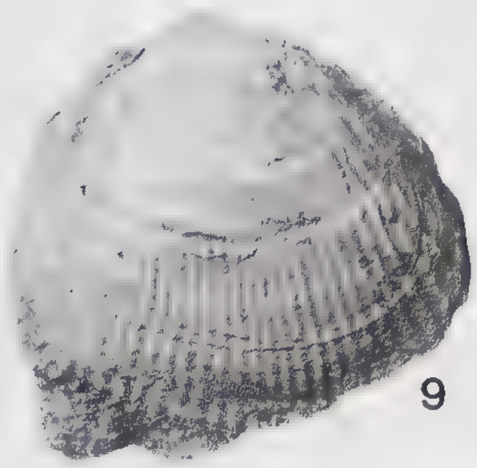
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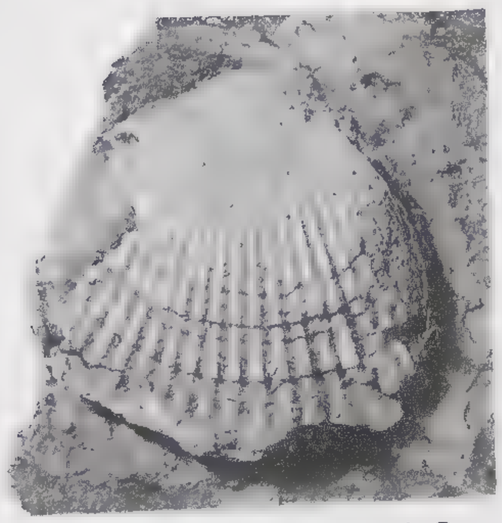
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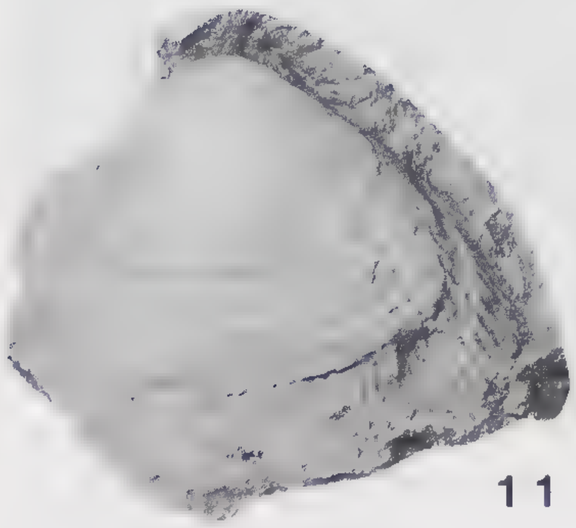
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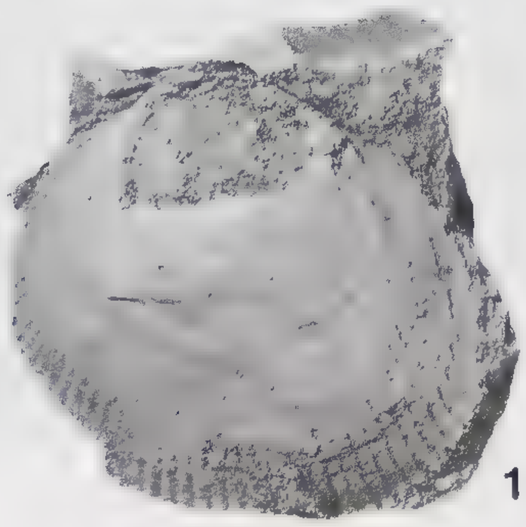
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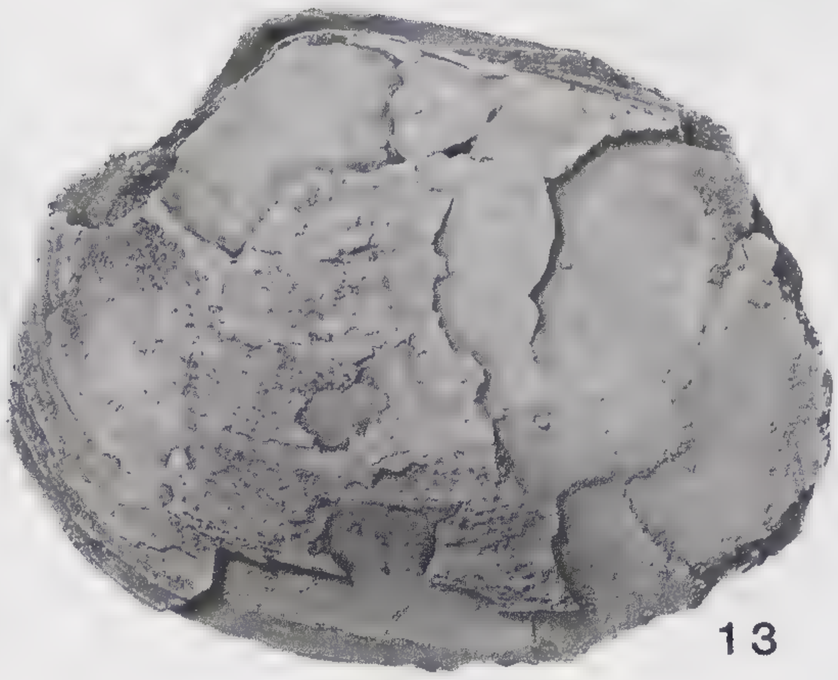
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EXPLANATION OF PLATE 15

Figure — Page

1. ***Clinocardium*** cf. ***C. ciliatum*** (Fabricius) 90
External cast of right valve, USNM 339767; length 21.5 mm, height 18.4 mm, ×1; USGS locality M7146.

2–4. ***Clinocardium hannibali*** Keen 91
2–3. Articulated valves, USNM 339768; length 23.3 mm, height 18.7 mm, ×2; USGS locality M7149.
2. Left valve.
3. Right valve.
4. External mold of right valve, USNM 339769; length 26.0 mm, height 23.4 mm, ×1.5; USGS locality M7150.

5–8. ***Clinocardium meekianum*** (Gabb) n. subsp.? 92
5. Left valve, USNM 339770; length 55.7 mm, height 45.7 mm, ×1; USGS locality M7146.
6–7. Articulated valves, USNM 339771; length 71.0 mm, height 77.9 mm, ×0.75; USGS locality M7201.
6. Right valve.
7. Left valve.
8. External mold of left valve, USNM 339772; length 70.0 mm, height 65.4 mm, ×1; USGS locality M7146.

9–12. ***Clinocardium*** cf. ***C. pristinum*** Keen 92
9. External mold of right valve, USNM 339773; length 38.7 mm, height 36.0 mm, ×1; USGS locality M7146.
10. Right valve, USNM 339774; showing nodose radial costae; length 25.3 mm, height 26.0 mm, ×1.5; USGS locality M7140.
11. External mold of left valve, USNM 339775; length 42.5 mm, height 38.6 mm, ×1; USGS locality M7146.
12. External mold of left valve, USNM 339776; length 39.4 mm, height 38.0 mm, ×1; USGS locality M7146.

13. ***Saxidomus*** sp. indet. 93
Left valve of articulated valves, USNM 339777; showing largely decorticated shell; length 68.9 mm, height 52.2 mm, ×1; USGS locality M7139.

EXPLANATION OF PLATE 16

Figure — Page

1–4. ***Protothaca (Protothaca) staleyi*** (Gabb) 93

1–3. Articulated valves, USNM 339778; length 48.5 mm, height 43.8 mm, thickness 31.3 mm, ×1; USGS locality M7142.

1. Left valve.
2. Dorsal view.
3. Right valve.

4. Right valve, USNM 339779; length 40.0 mm, height 34.5 mm, ×1; USGS locality M7140.

5–7. ***Spisula (Mactromeris) albaria*** (Conrad) 95

Articulated valves, USNM 339780; length 53.1 mm, height 40.3 mm, thickness 23.0 mm, ×1; USGS locality M7139.

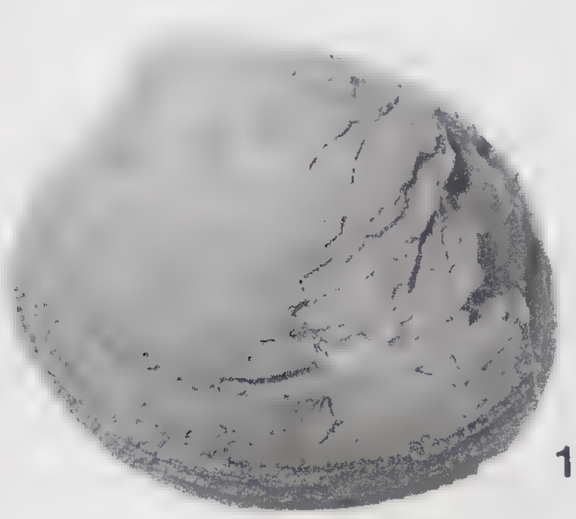
5. Left valve.
6. Dorsal view.
7. Right valve.

8–9. ***Spisula (Mactromeris) brevirostrata*** Packard 95

8. Left valve, USNM 339781; length 79.5 mm, height 60.2 mm, ×1; USGS locality M7146.
9. Right valve, USNM 339782; length 68.1 mm, height 52.2 mm, ×1; USGS locality M7150.

10–12. ***Spisula (Mactromeris) polynyma*** (Stimpson) 96

10. Right valve, USNM 339783; length 48.1 mm, height 25.5 mm, ×1; USGS locality M7146.
11. Left valve, USNM 339784; length 76.4 mm, height 52.6 mm, ×1; USGS locality M7146.
12. Left valve, USNM 339785; length 36.0 mm, height 22.8 mm, ×1; USGS locality M7146.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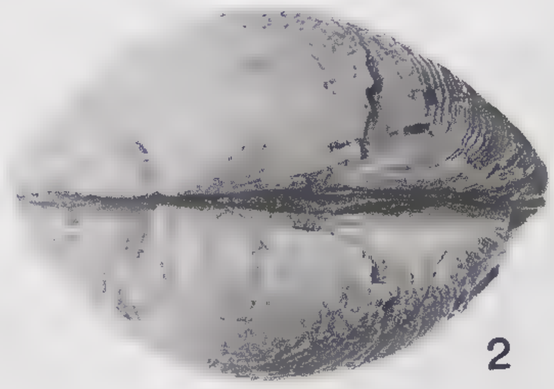
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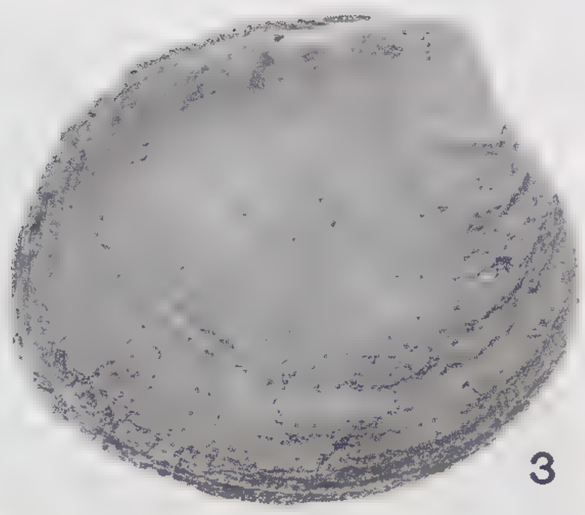
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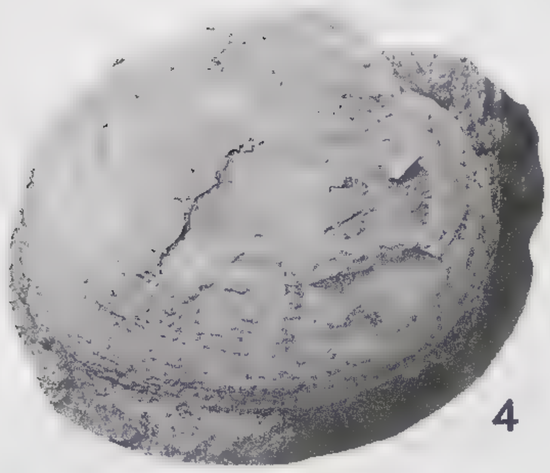
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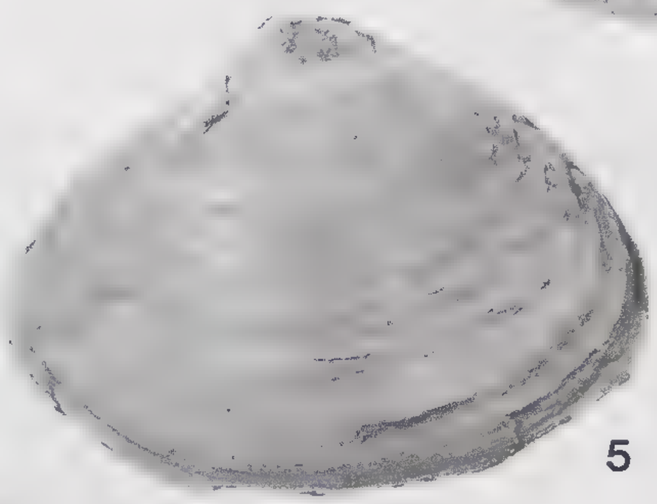
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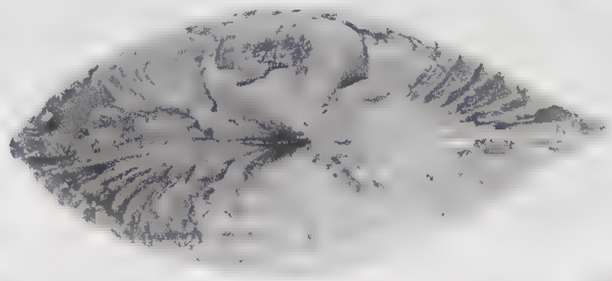
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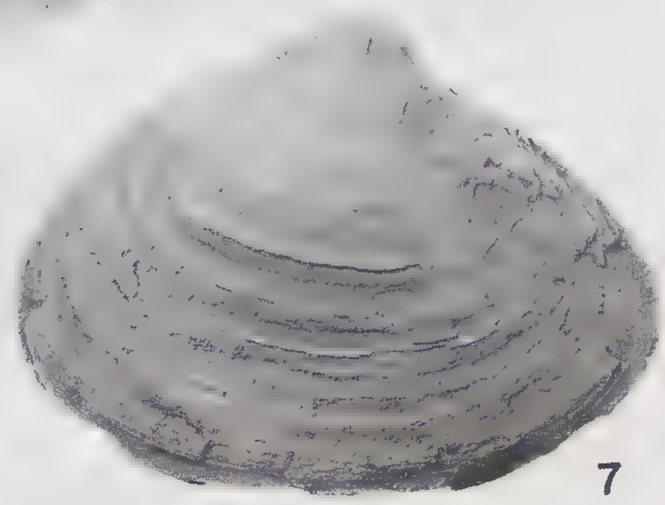
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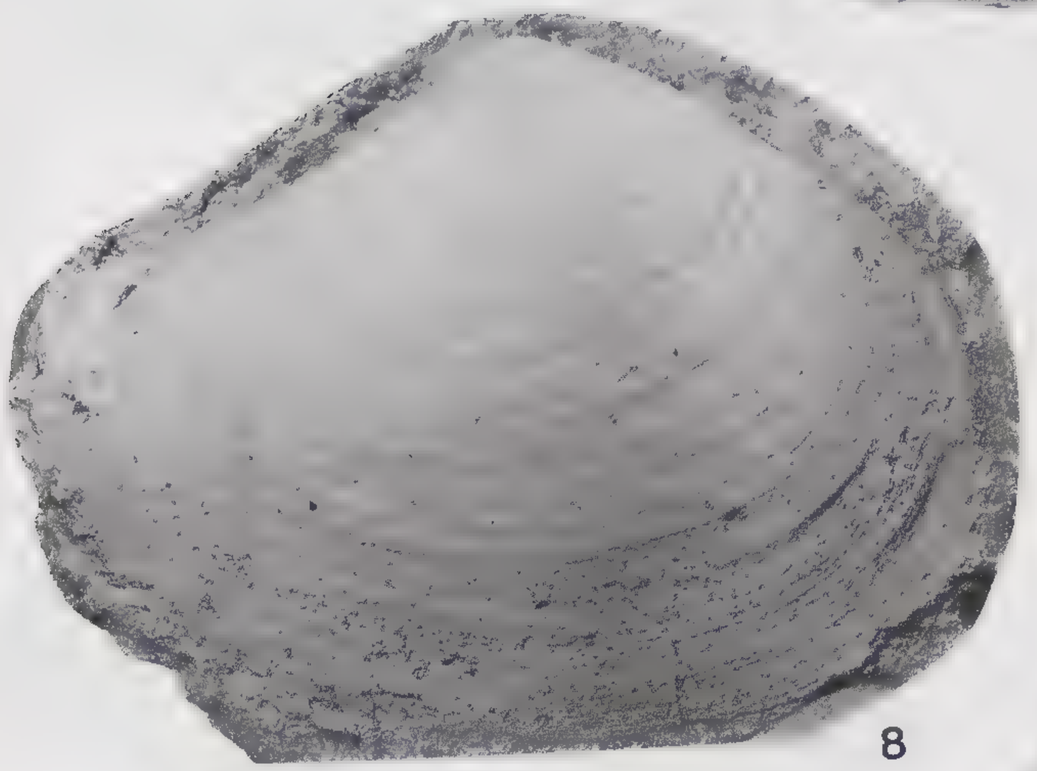
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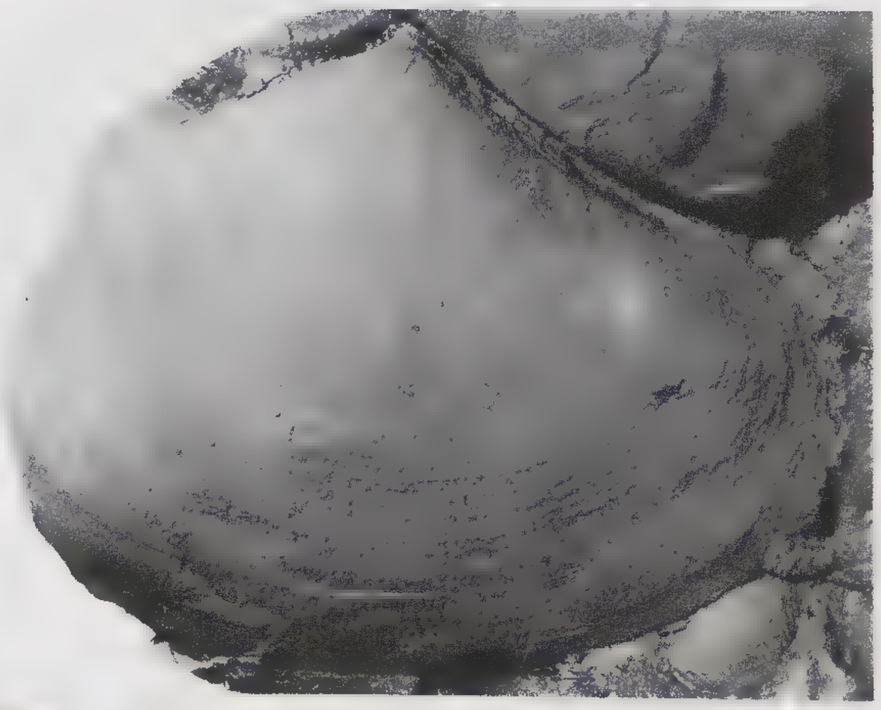
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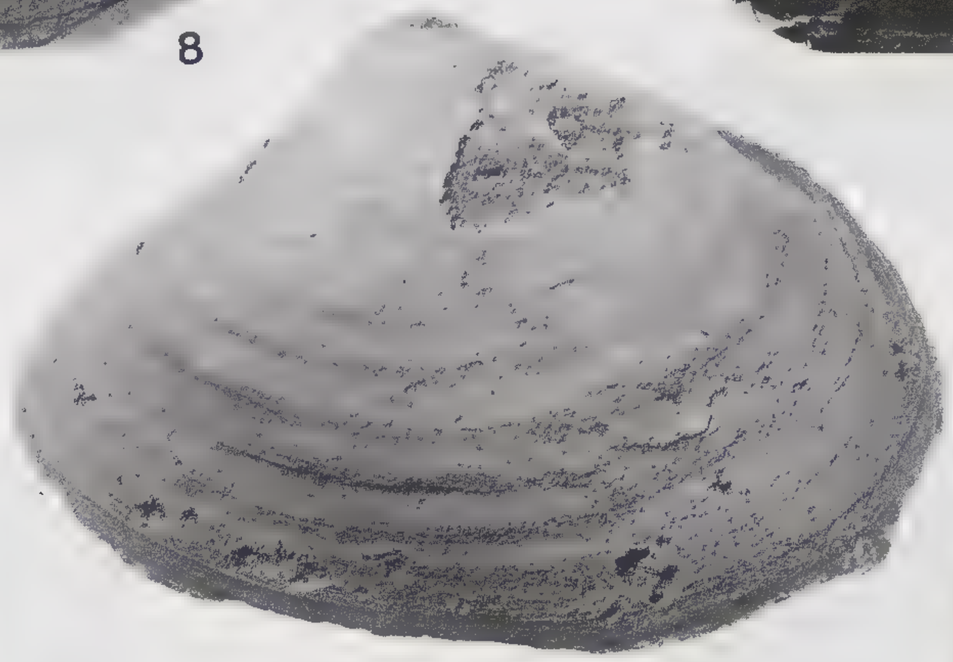
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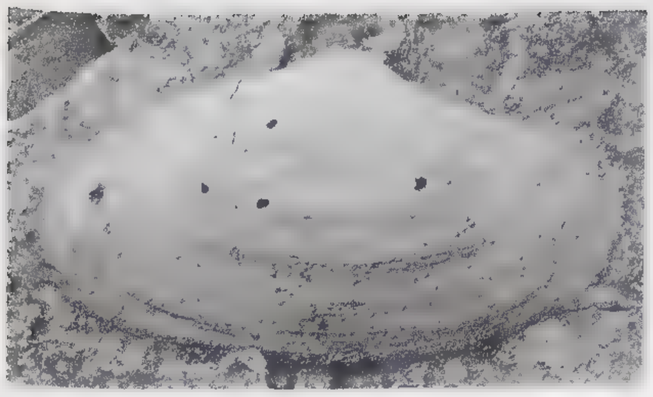
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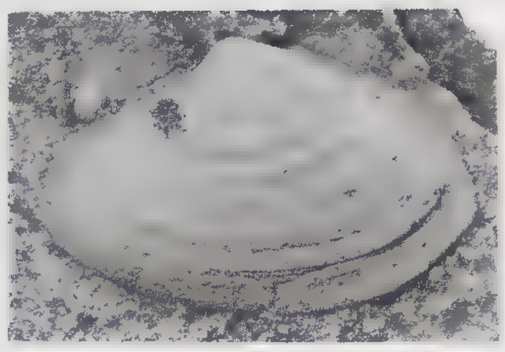
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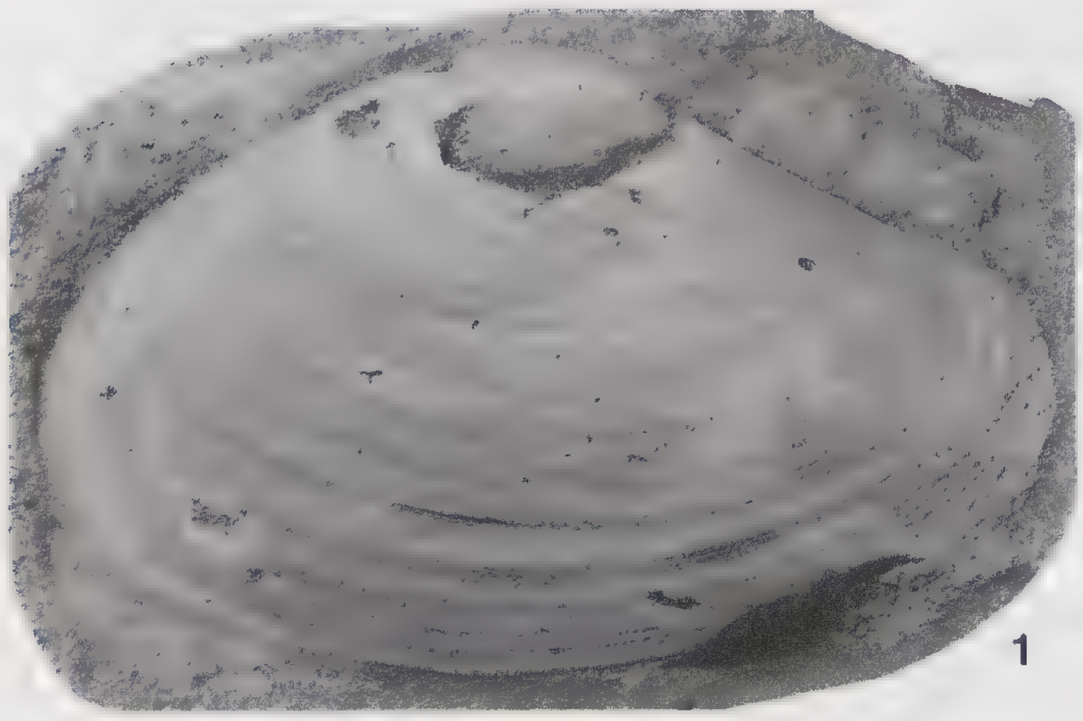

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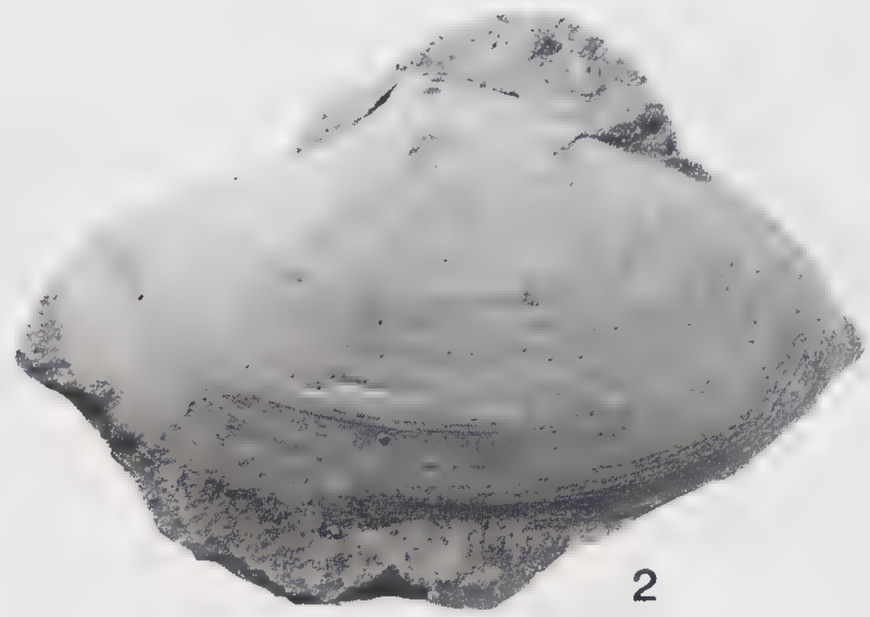

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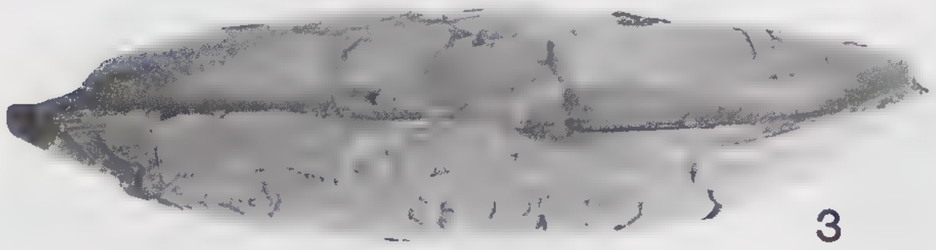

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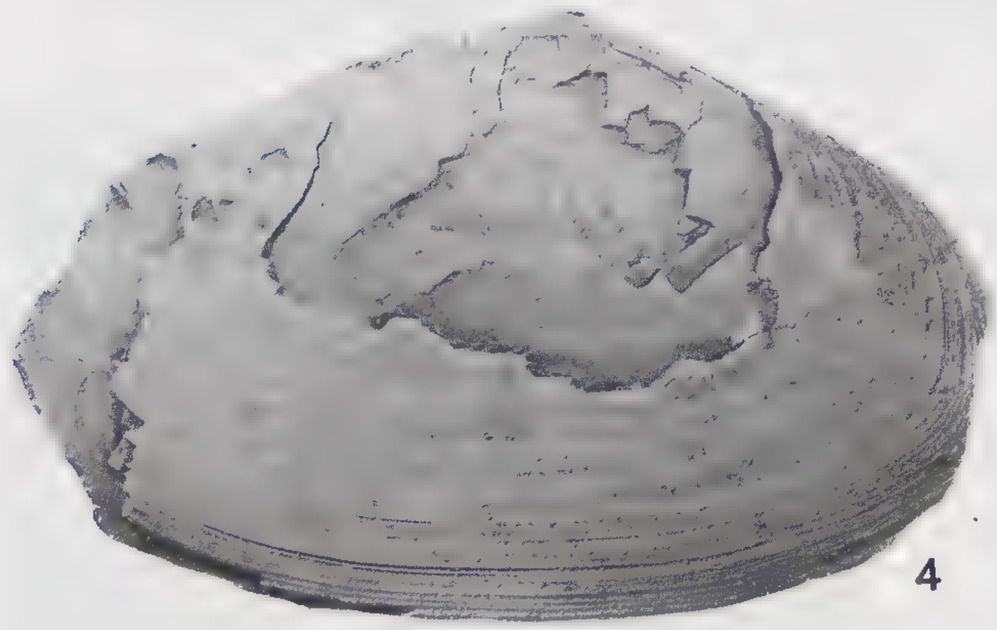

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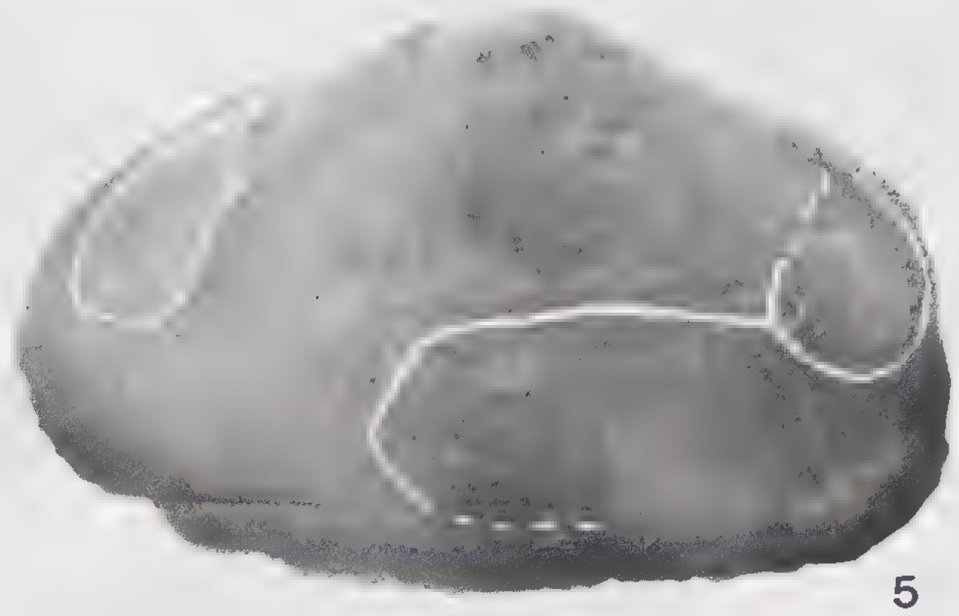

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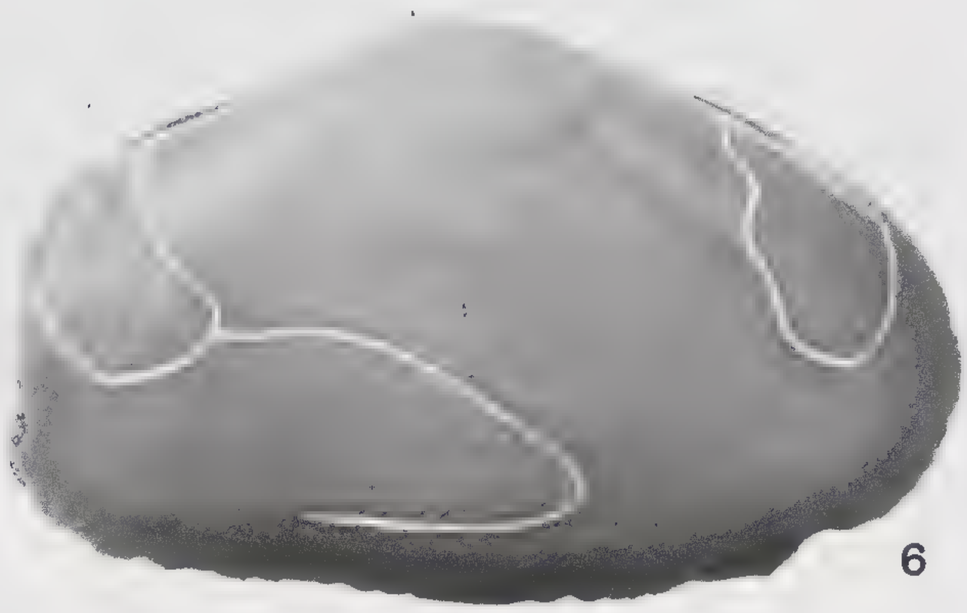

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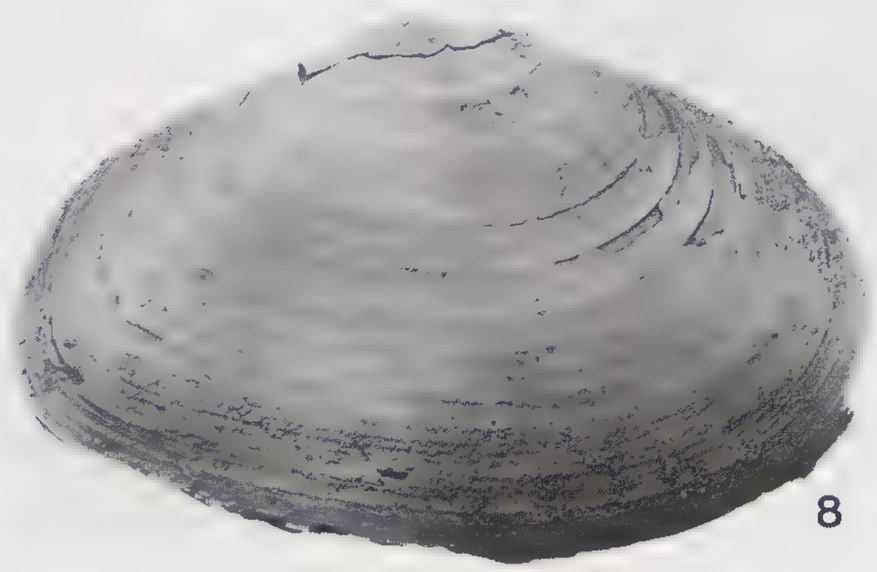

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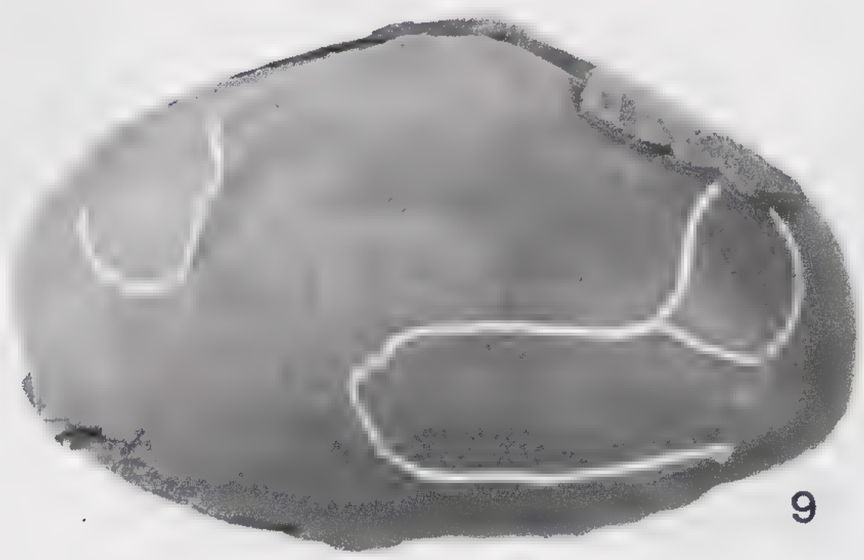

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EXPLANATION OF PLATE 17

Figure

1–2. ***Spisula (Mactromeris) polynyma*** (Stimpson) 96
1. Right valve, USNM 339786; length 81.8 mm, height 53.7 mm, ×1; USGS locality M7258.
2. Left valve, USNM 339787; length 65.0 mm, height 36.1 mm, ×1; USGS locality M7146.
3–9. ***Peronidia*** aff. ***P. lutea alternidentata*** (Broderip and Sowerby) 97
3–4. Articulated valves, USNM 339788; length 79.1 mm, height 50.0 mm, thickness, 19.9 mm, ×1; USGS locality M7139.
3. Dorsal view.
4. Right valve.
5–6. Internal mold of articulated valves, UA 2477; showing pallial sinus and adductor muscle scars [inked in by author]; length 77.0 mm, height, 48.3 mm, ×1; UA locality A-170.
5. Left valve.
6. Right valve.
7–9. Articulated valves, UA 2478; length 70.3 mm, height 45.6 mm, thickness 19.2 mm, ×1; UA locality A-170.
7. Dorsal view.
8. Right valve.
9. Internal mold of left valve, showing pallial sinus and adductor muscle scars [inked in by author].

Page

EXPLANATION OF PLATE 18

Figure — Page

1–3. ***Peronidia*** aff. ***P. lutea alternidentata*** (Broderip and Sowerby) 97
Articulated valves, USNM 339789; length 52.9 mm, height 29.0 mm, thickness 8.4 mm, ×1; USGS locality M7139.
1. Left valve.
2. Dorsal view.
3. Right valve.

4–18. ***Macoma (Macoma)*** cf. ***M. (M.) astori*** Dall 97
4. Left valve, USNM 339790; length 35.8 mm, height 27.6 mm, ×1; USGS locality M7140.
5. Right valve, USNM 339791; length 42.4 mm, height 30.0 mm, ×1; USGS locality M7140.
6. Right valve, USNM 339792; length 41.0 mm, height 30.0 mm, ×1; USGS locality M7140.
7. Left valve, USNM 339793; length 37.0 mm, height 26.4 mm, ×1; USGS locality M7140.
8. Left valve, USNM 339794; length 37.5 mm, height 28.5 mm; ×1; USGS locality M7142.
9. Left valve, USNM 339795; length 40.3 mm, height 31.7 mm, ×1; USGS locality M7140.

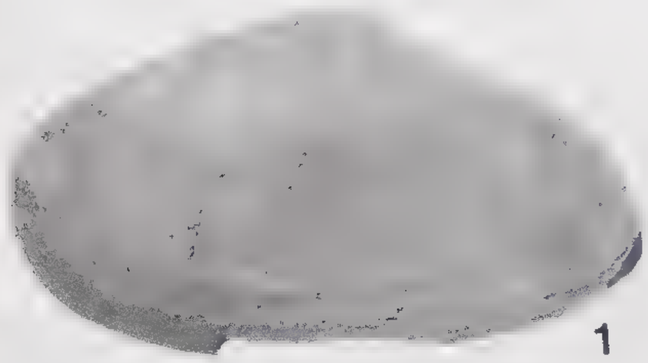
10–12. Articulated valves, USNM 339796; length 42.4 mm, height 39.0 mm, thickness 9.4 mm, ×1; USGS locality M7140.
10. Dorsal view.
11. Right valve.
12. Left valve.

13–14. Articulated valves, USNM 339797; length 36.8 mm, height 31.4 mm, ×1; USGS locality M7140.
13. Left valve.
14. Right valve.

15–16. Articulated valves, USNM 339798; length 39.1 mm, height 26.7 mm, thickness 10.9 mm, ×1; USGS locality M7140.
15. Dorsal view.
16. Left valve.

17. Internal mold of left valve, USNM 339799; showing pallial sinus and adductor muscle scars [inked in by author]; length 44.4 mm, height 36.4 mm, ×1; USGS locality M7142.
18. Right valve, USNM 339800; length 42.1 mm, height 33.0 mm, ×1; USGS locality M7142.

19. ***Macoma incongrua*** (von Martens) 100
Right valve, USNM 339801; length 37.8 mm, height 31.0 mm, ×1; USGS locality M7146.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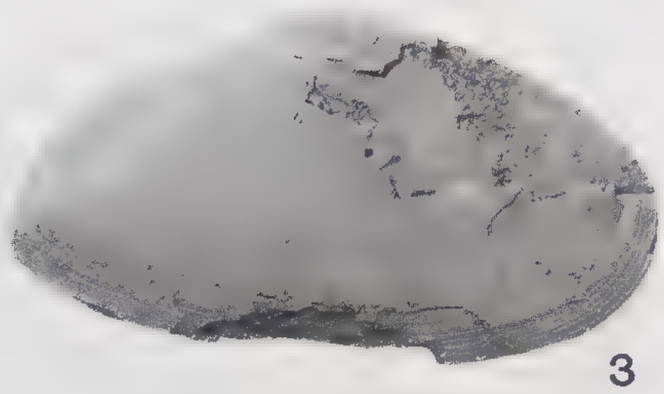
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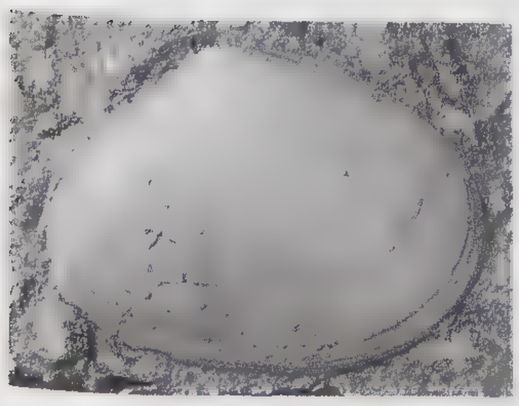
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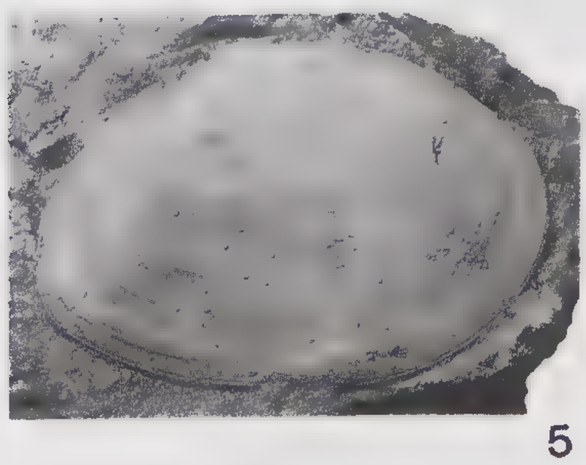
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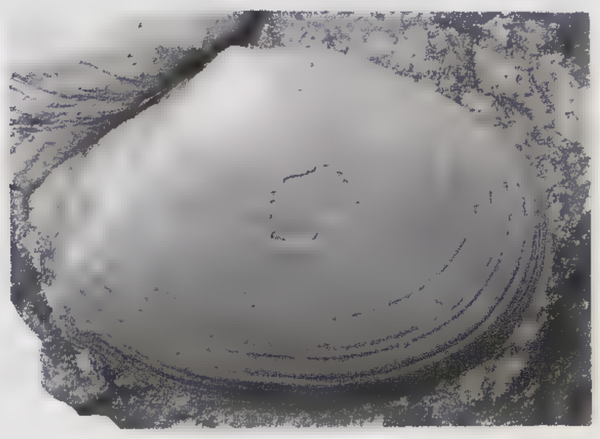
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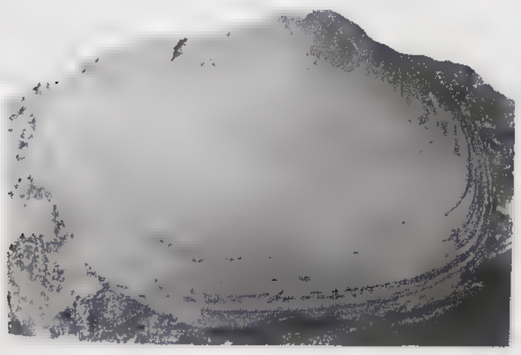
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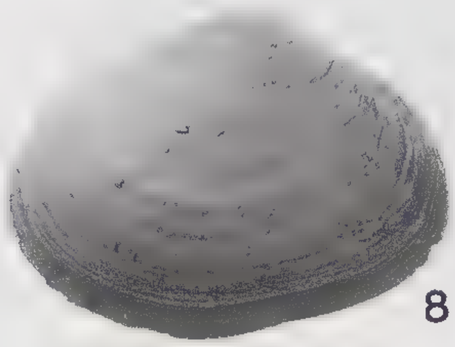
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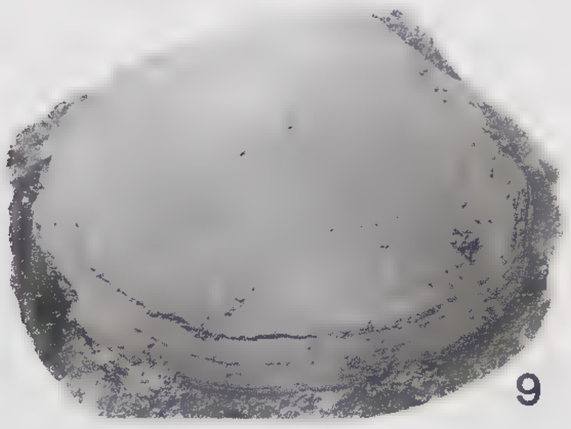
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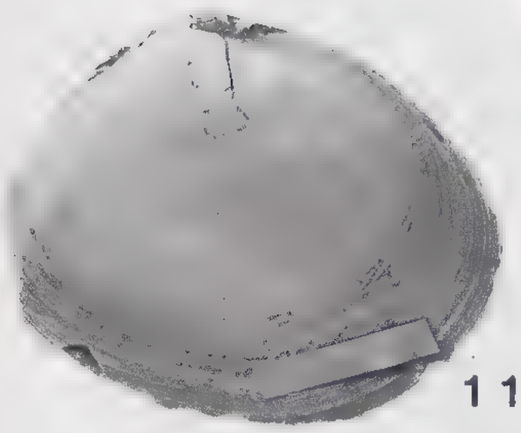
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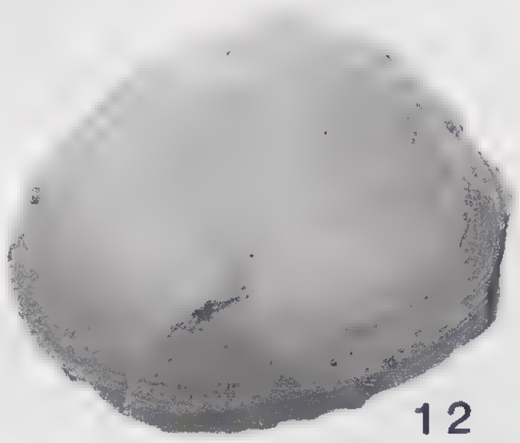
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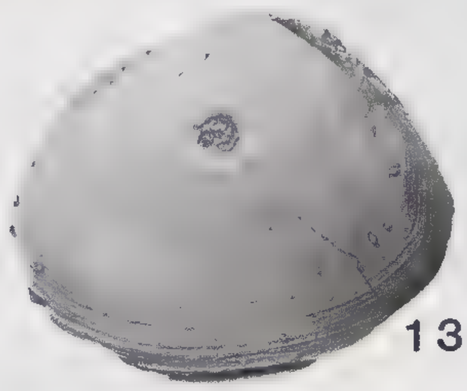
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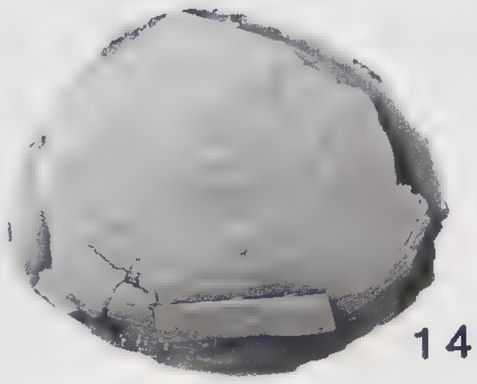
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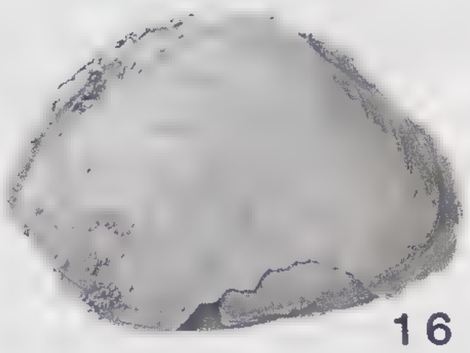
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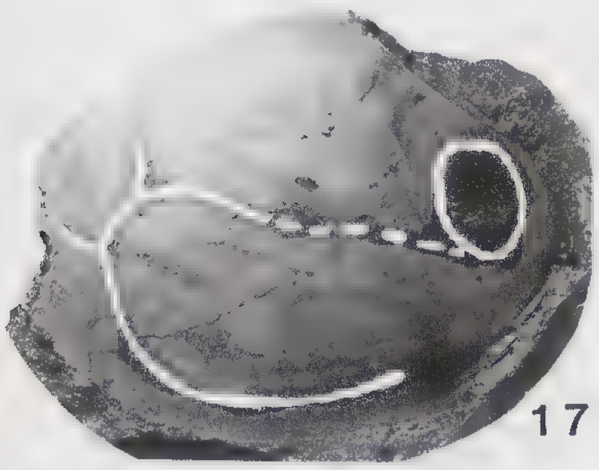
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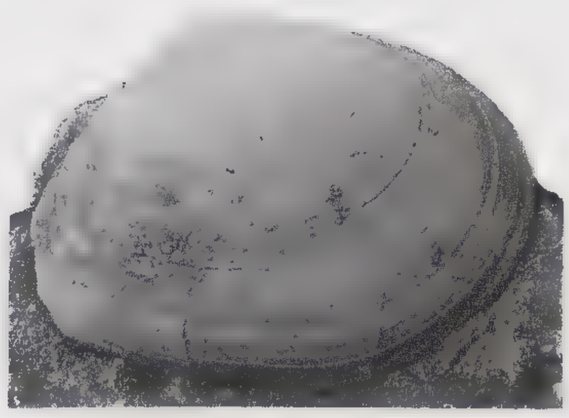
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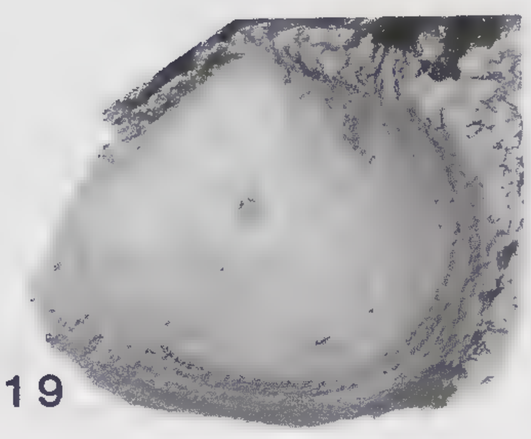
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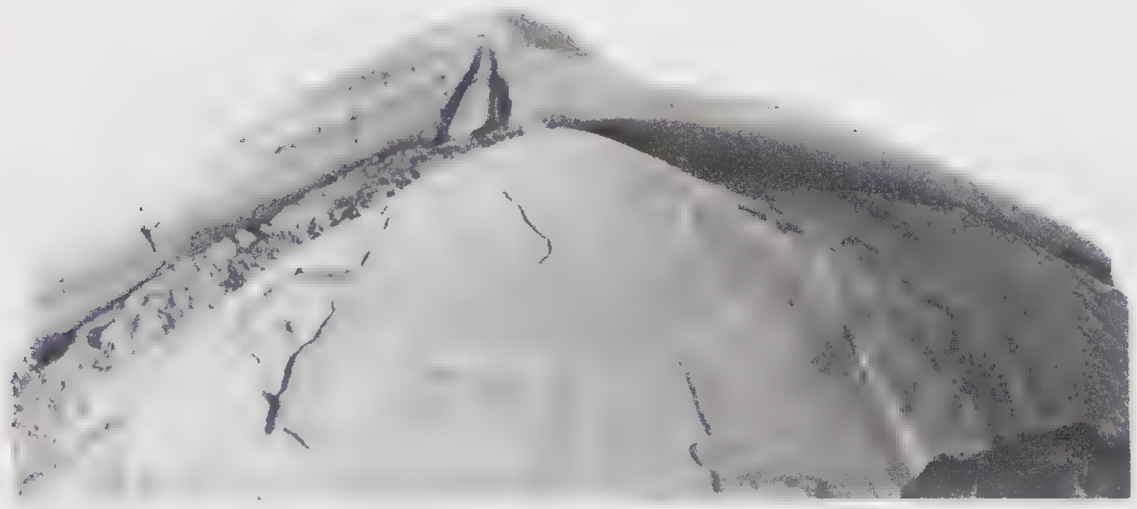

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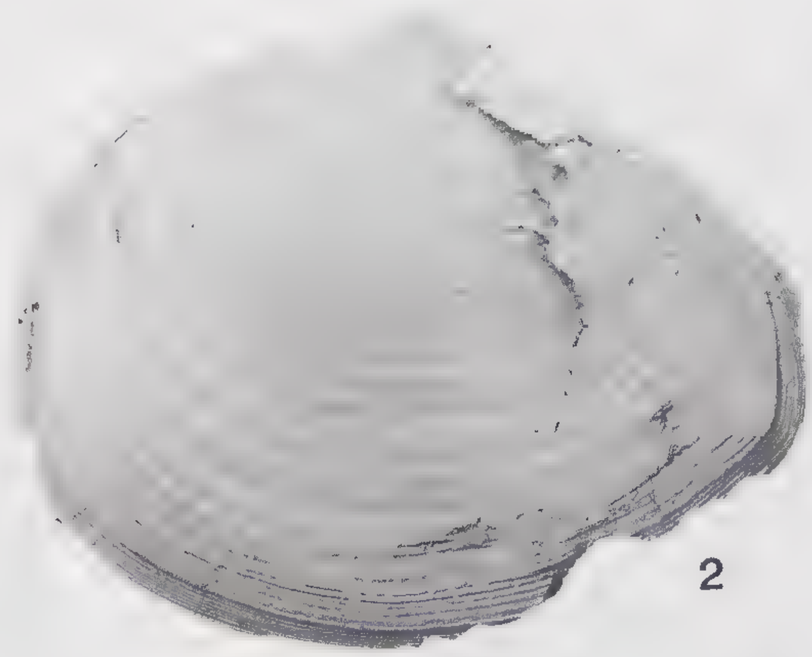

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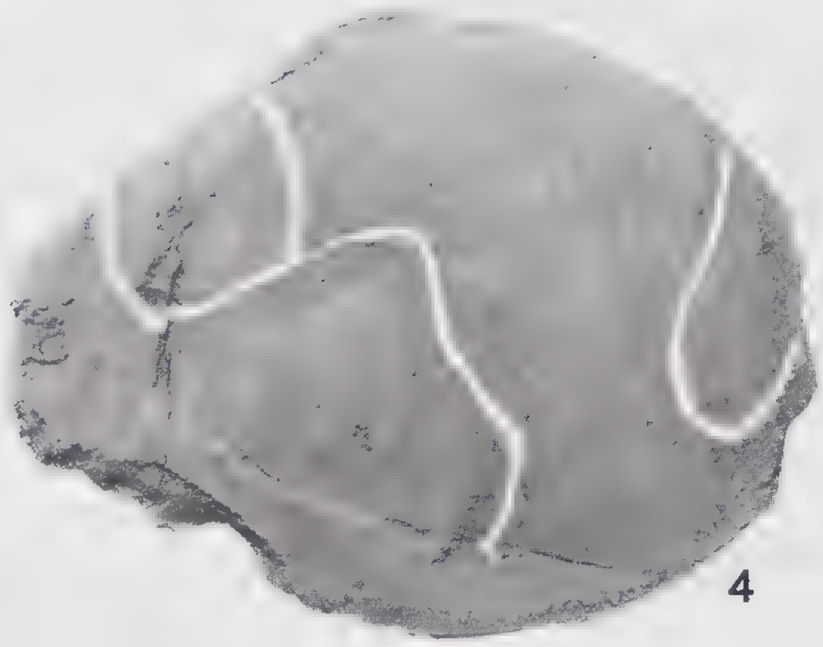

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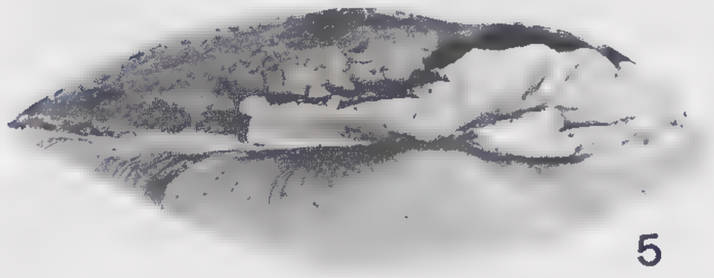

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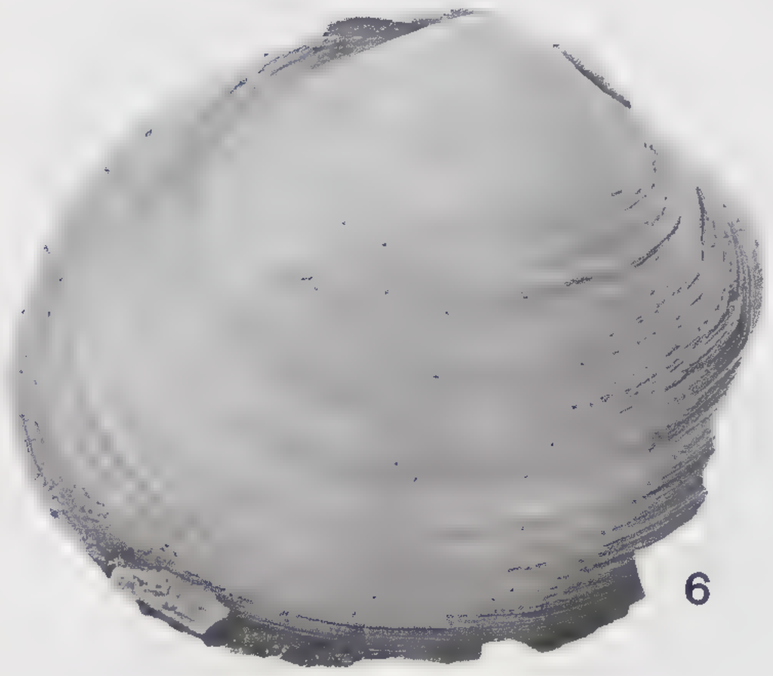

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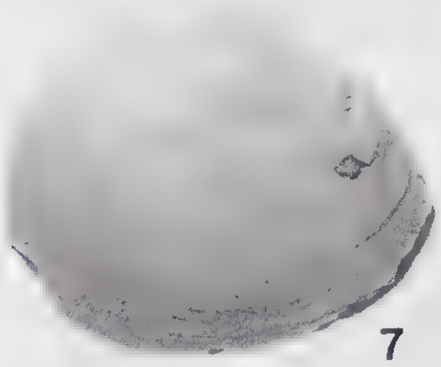

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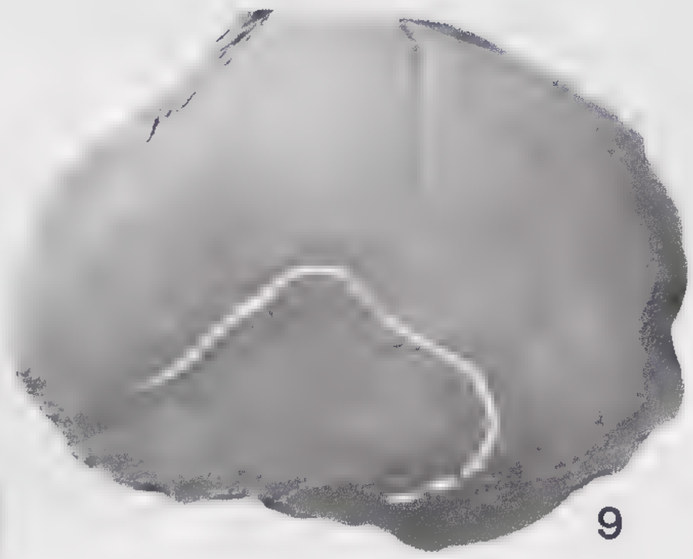

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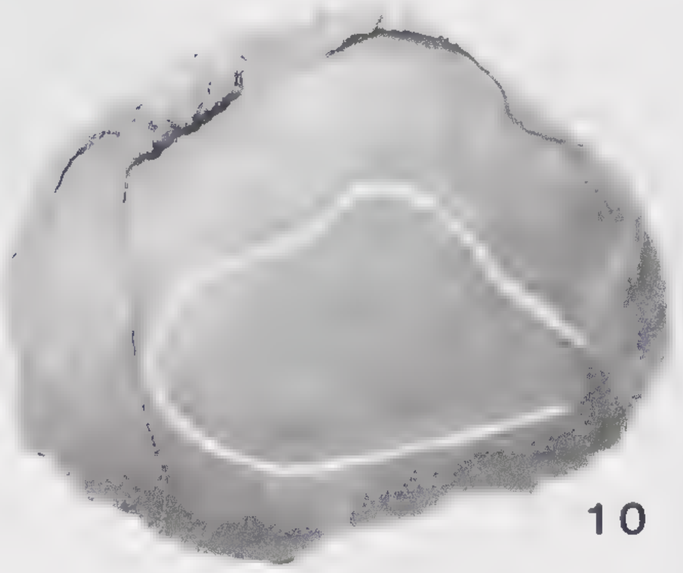

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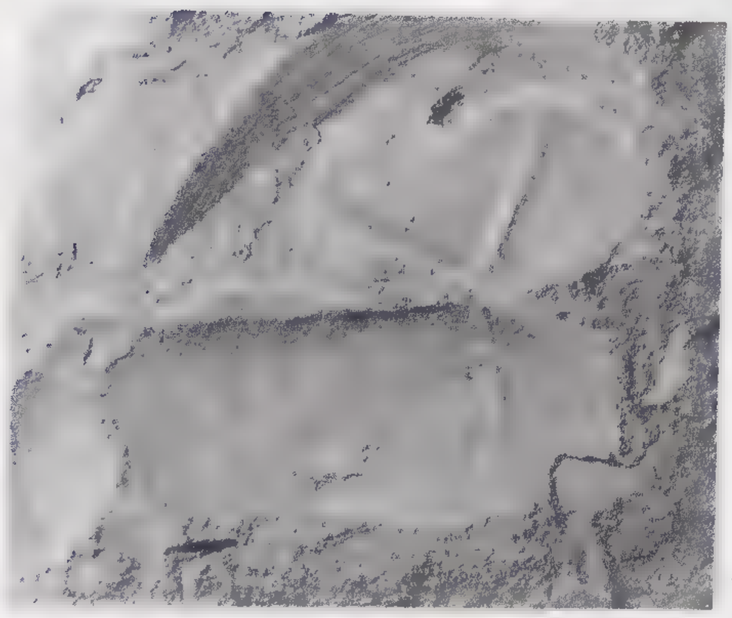

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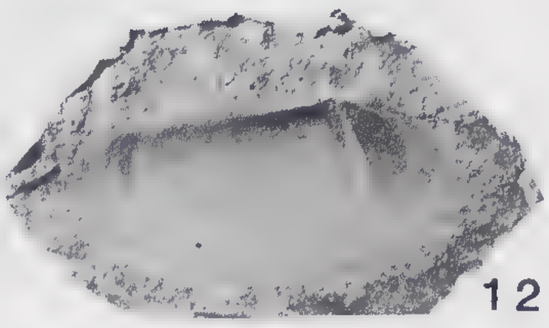

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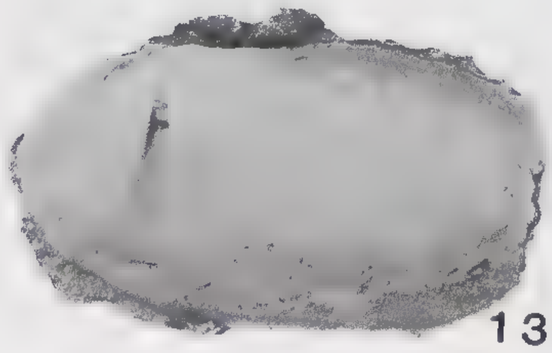

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EXPLANATION OF PLATE 19

Figure — Page

1–10. ***Macoma (Macoma) optiva*** (Yokoyama) 98

1. Left valve hinge, UA 2479; ×2; UA locality A-169.

2–4. Articulated valves, UA 2480; length 65.4 mm, height 52.5 mm, thickness 15.6 mm, ×1; UA locality A-170.

2. Left valve.

3. Dorsal view, showing posterior flexure to the right.

4. Internal mold of right valve, showing part of pallial sinus and adductor muscle scars [inked in by author].

5–6. Articulated valves, UA 2481; length 60.0 mm, height 54.5 mm, thickness 23.1 mm, ×1; UA locality A-170.

5. Dorsal view.

6. Left valve.

7. Left valve of juvenile specimen, UA 2482; length 35.5 mm, height 29.6 mm, ×1; UA locality A-170.

8–10. Internal mold of articulated valves, UA 2483; length 55.7 mm, height 47.3 mm, thickness 15.6 mm, ×1; UA locality A-170.

8. Dorsal view.

9. Right valve, showing part of pallial sinus [inked in by author].

10. Left valve, showing pallial sinus [inked in by author].

11–13. ***Siliqua*** cf. ***S. alta*** (Broderip and Sowerby) 100

11. Internal mold of articulated, open valves, USNM 339802; length 42.0 mm, height 18.5 mm (of left valve, bottom), ×1; USGS locality M7146.

12. Latex cast of left valve, USNM 339803; length 32.0 mm, height 16.4 mm, ×1; USGS locality M7146.

13. Internal mold of left valve, UA 2484; length 42.9 mm, height 24.5 mm, ×1; UA locality A-301.

EXPLANATION OF PLATE 20

Figure — Page

1. ***Siliqua*** cf. ***S. alta*** (Broderip and Sowerby) 100
Internal mold of articulated valves, USNM 339804; length 59.3 mm, height 28.1 mm (of right valve, below), ×1; USGS locality M7150.

2–6. ***Mya (Mya) truncata*** Linnaeus 101

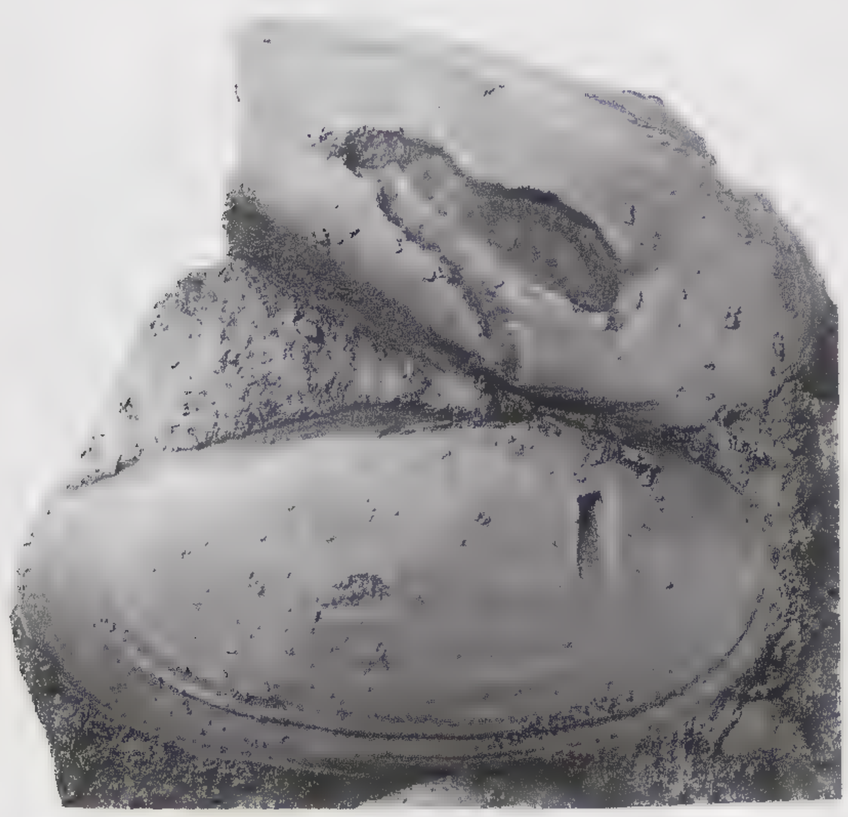
2–3. Articulated valves, USNM 339805; length 77.0 mm, height 59.1 mm, thickness 43.2 mm, ×1; USGS locality M7142.
2. Dorsal view.
3. Left valve.

4–5. Articulated valves, USNM 339806; length 76.1 mm, height 52.7 mm, thickness 34.5 mm, ×1; USGS locality M7146.
4. Dorsal view.
5. Right valve.

6. Right valve of juvenile, UA 2485; showing truncated posterior end; length 32.3 mm, height 22.5 mm, ×1; UA locality A-301.

7. Left valve of juvenile questionably assigned to the species, UA 2486; with imperfectly truncate posterior end; length 39.7 mm, height 24.2 mm, ×1; UA locality A-301.

8–9. ***Mya (Arenomya) elegans*** (Eichwald) 102
Articulated valves, USNM 339807; length 80.9 mm, height 58.2 mm, thickness 40.7 mm, ×1; USGS locality M7146.
8. Dorsal view.
9. Right valve, showing narrowly rounded posterior end.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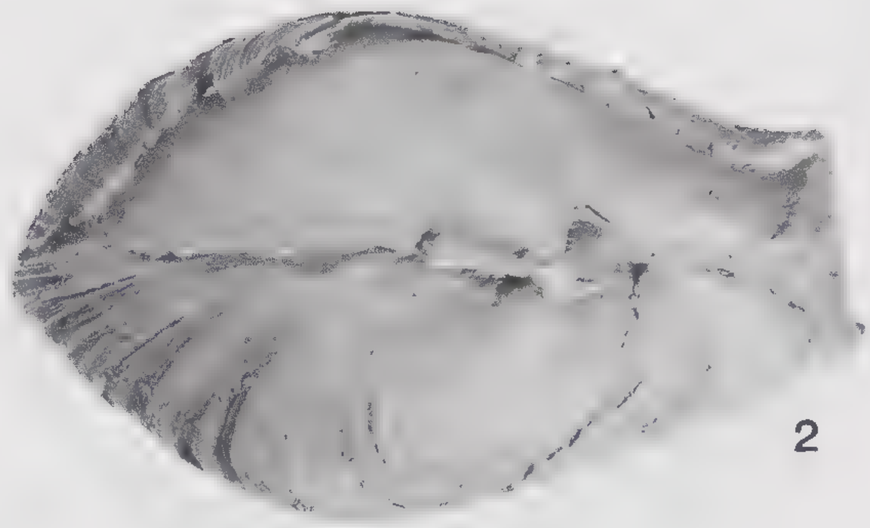
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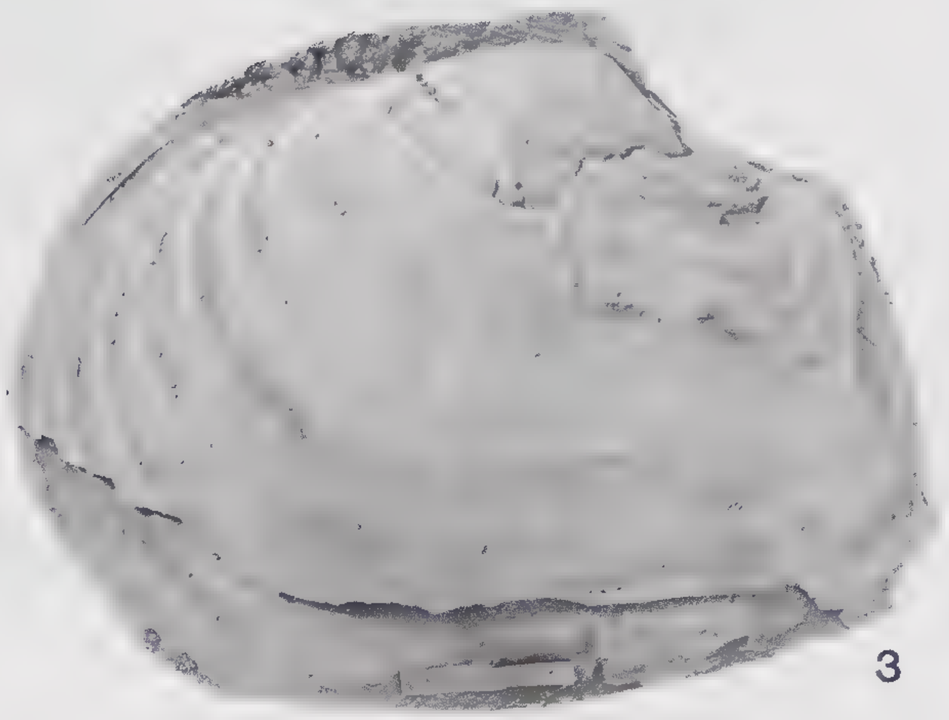
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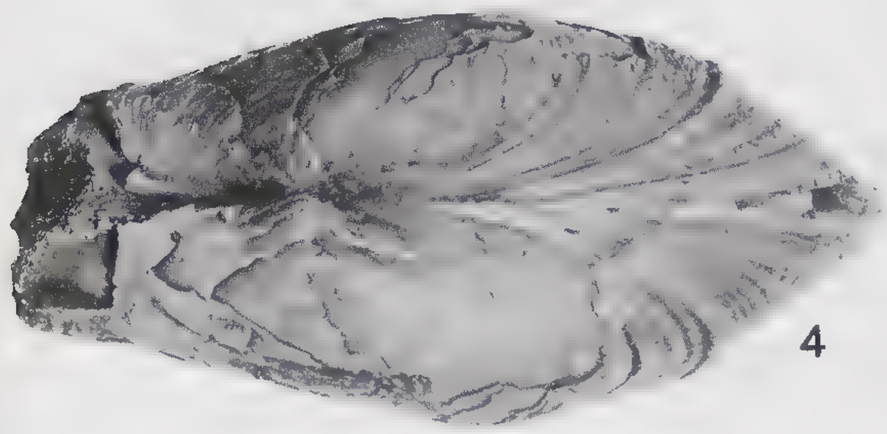
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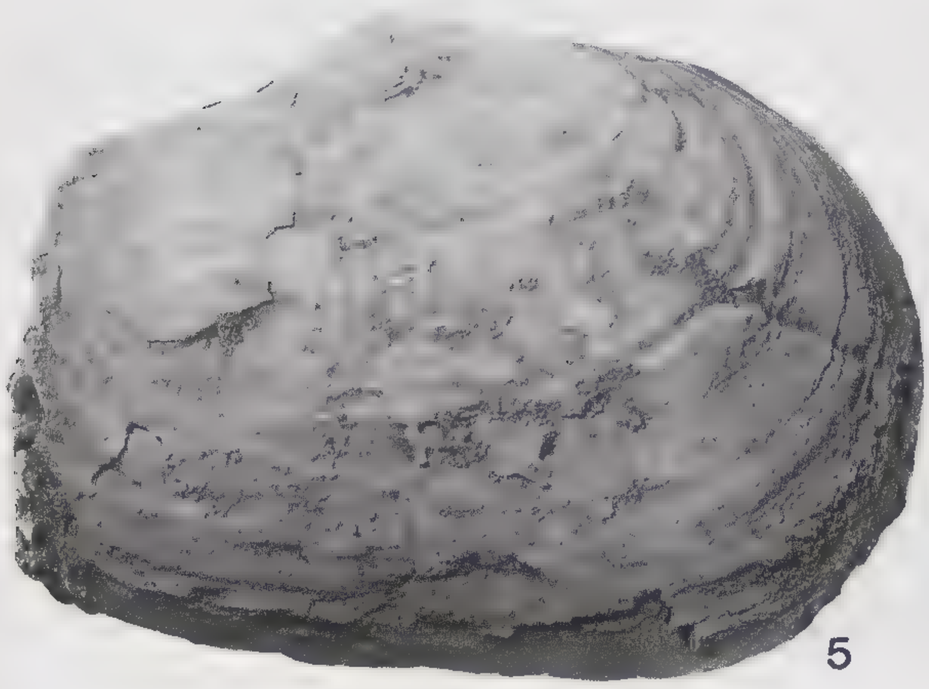
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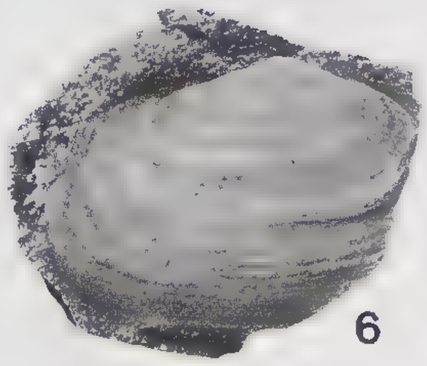
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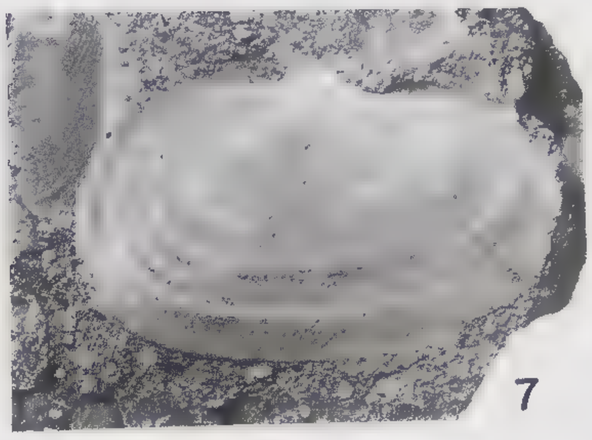
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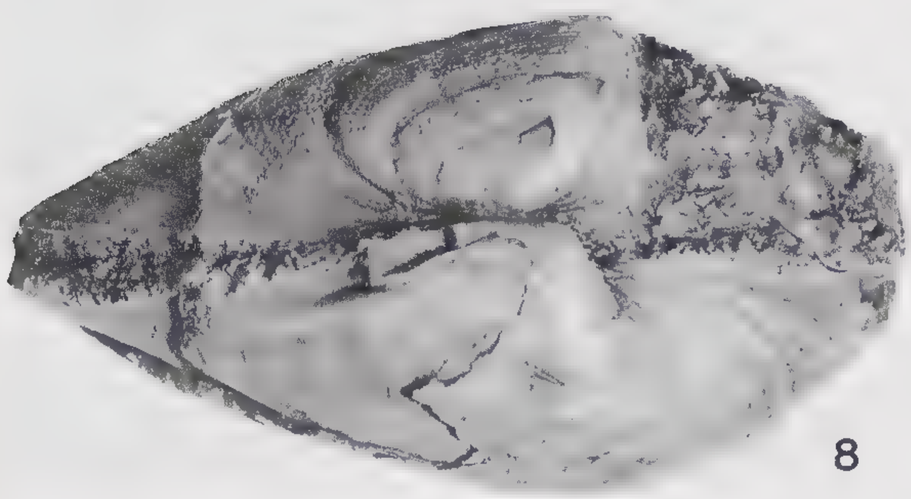
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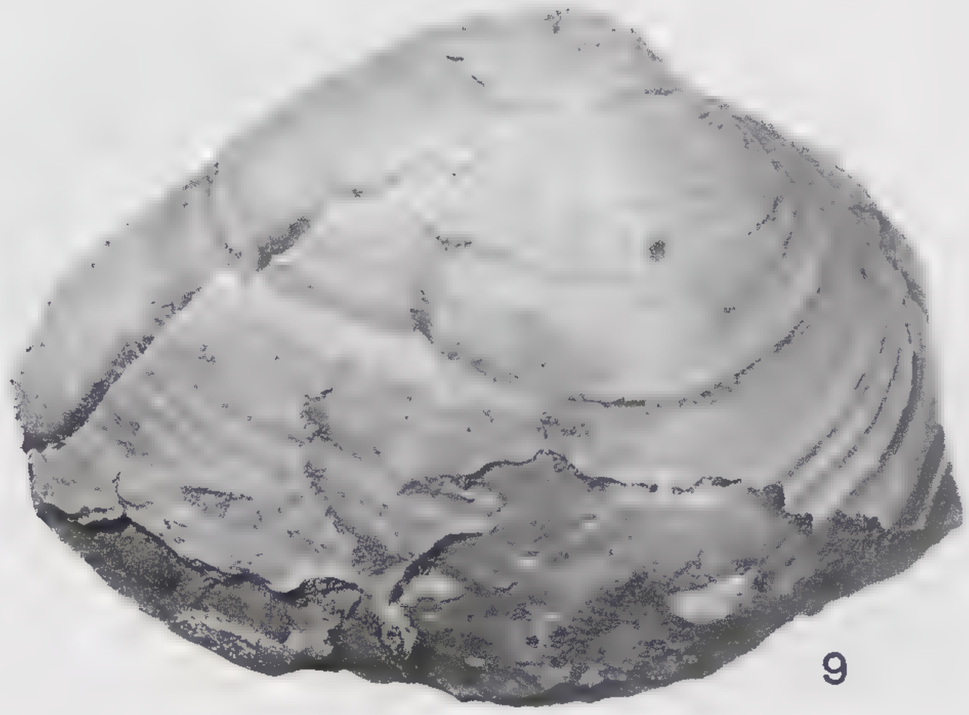
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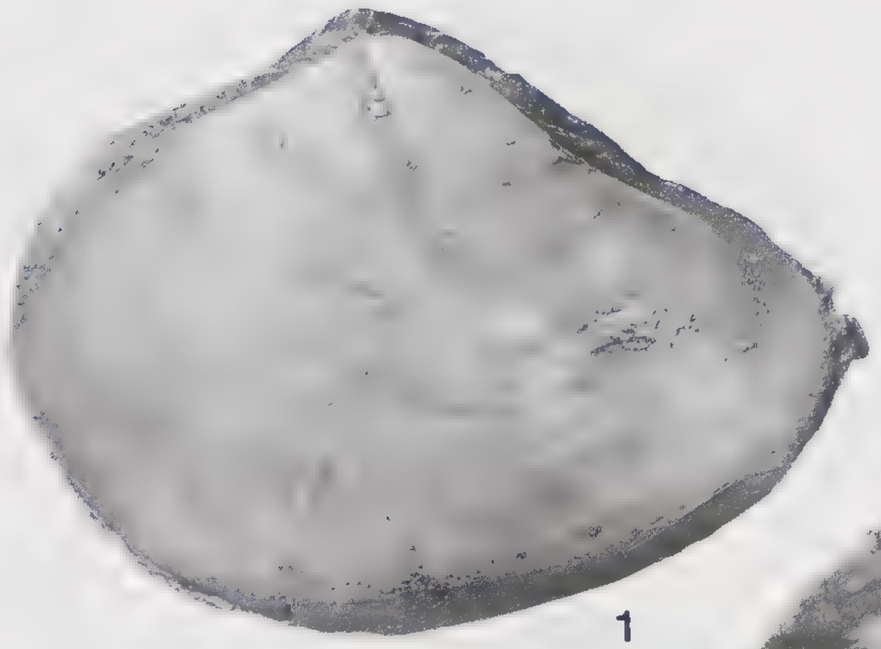
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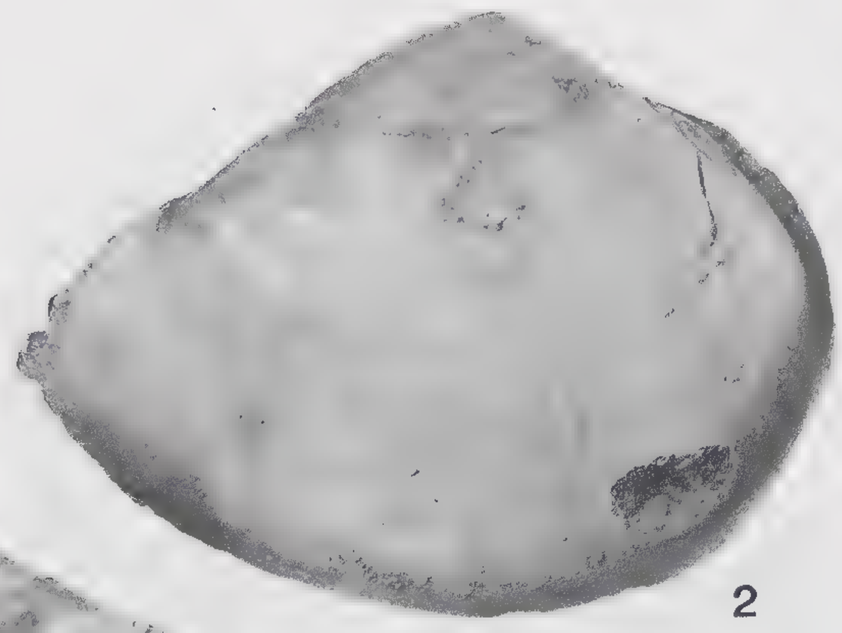
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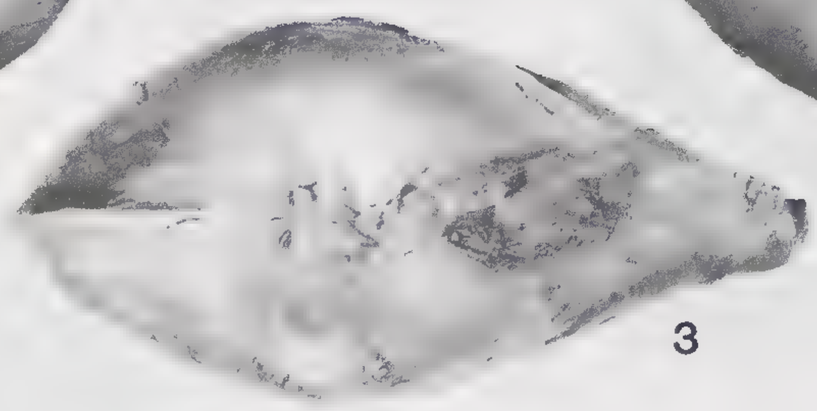
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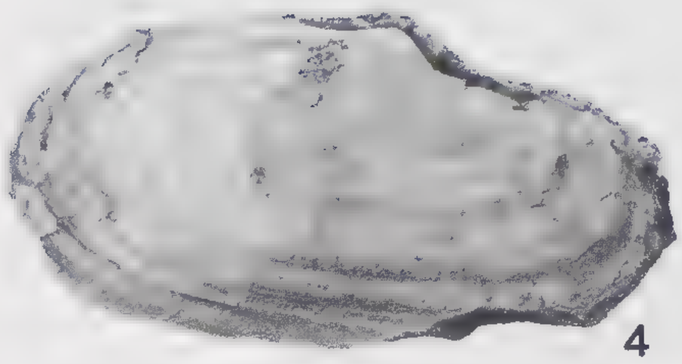
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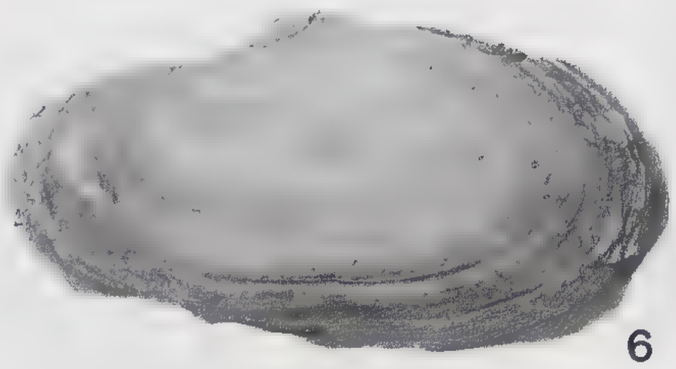
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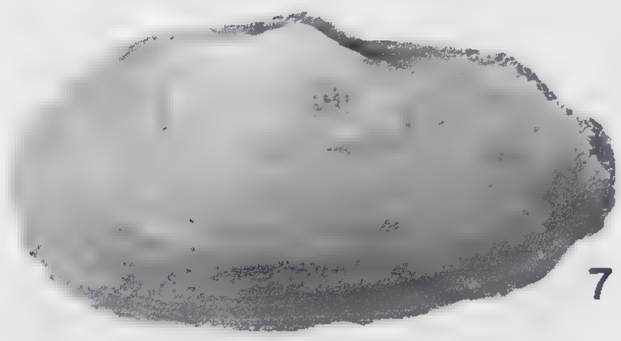
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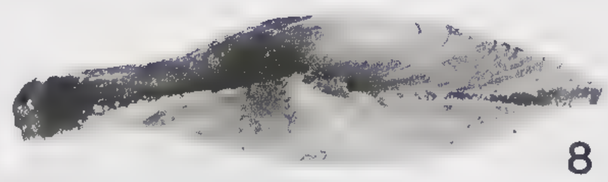
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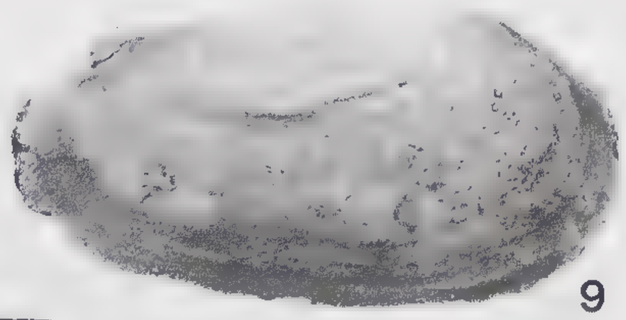
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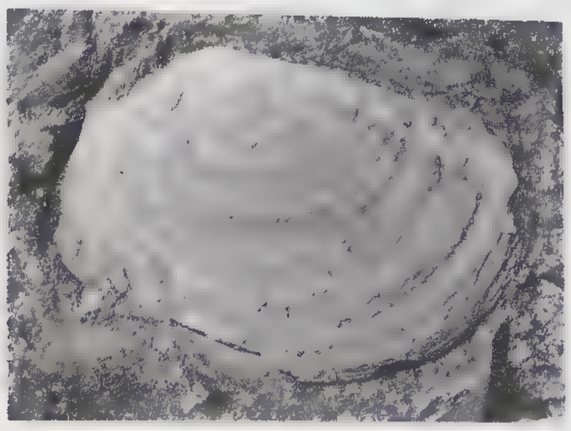
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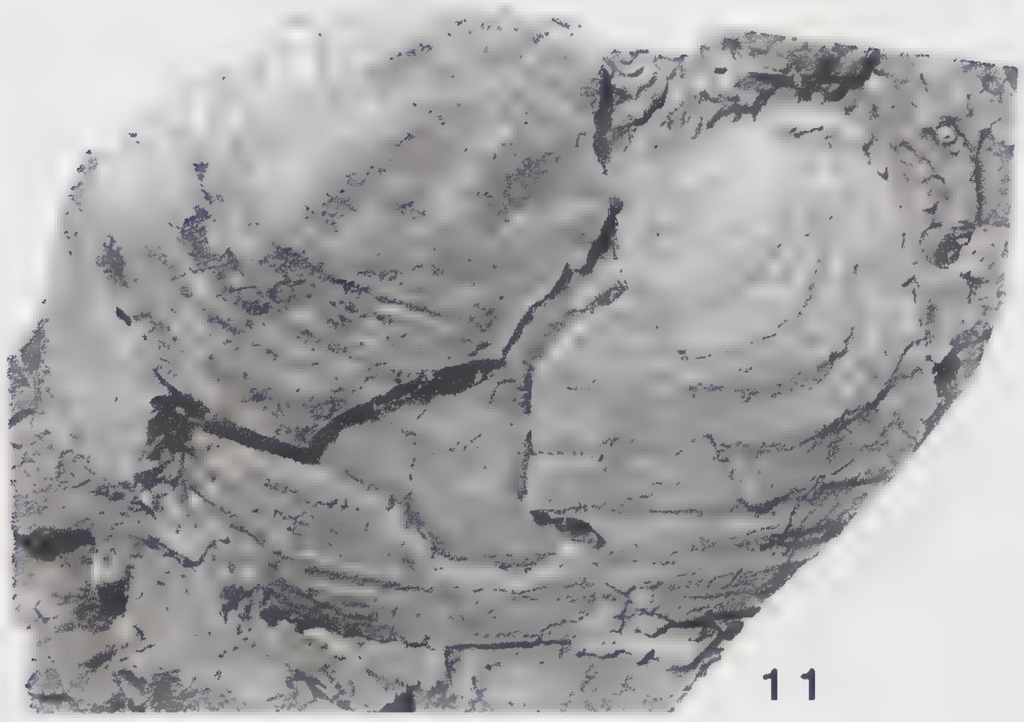
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EXPLANATION OF PLATE 21

Figure Page

1–3. ***Mya (Arenomya) elegans*** (Eichwald) 102
Internal mold of articulated valves, showing outline of pallial sinus, USNM 339808; length 101.0 mm, height 77.5 mm, thickness 42.7 mm, ×0.67; USGS locality M7139.
1. Left valve.
2. Right valve.
3. Dorsal view.

4–9. ***Mya*** new species 104
4–6. Articulated valves, UA 2487; length 55.4 mm, height 29.0 mm, thickness 15.8 mm, ×1; UA locality A-301.
4. Left valve.
5. Dorsal view, showing flared posterior gape.
6. Right valve.
7–9. Articulated valves, UA 2488; length 50.2 mm, height 27.0 mm, thickness 13.0 mm, ×1; UA locality A-301.
7. Left valve.
8. Dorsal view, showing flared posterior gape.
9. Right valve.

10. ***Pandora (Pandorella) grandis*** Dall 107
Right valve, USNM 339811; length 37.5 mm, height 26.2 mm, ×1; USGS locality M7139.

11. ***Panomya izumo*** Nomura and Hatai 105
Left valve, USNM 339809; length 73.3 mm, height 52.4 mm, ×1; USGS locality M7143.

12. ***Panomya trapezoidis*** Strauch 106
Right valve, USNM 339810; length 48.7 mm, height 27.6 mm, ×1; USGS locality M7150.

EXPLANATION OF PLATE 22

Figure — Page

1–4. ***Lyonsia mooreae*** new species 107
1–3. Articulated valves, USNM 339812 (holotype); length 15.2 mm, height 10.0 mm, thickness 6.0 mm; USGS locality M7142.
1. Right valve, showing extremely fine beaded radial sculpture and posterior truncation, ×2.
2. Dorsal view, ×2.
3. Enlargement of right valve to show radial sculpture, ×3.
4. Left valve, USNM 339813 (paratype); length 9.9 mm, height 6.8 mm, ×2; USGS locality M7142.

5–9. ***Periploma (Periploma)*** cf. ***P. (P.) aleutica*** (Krause) 108
5. Right valve, UA 2489; length 52.8 mm, height 39.0 mm, ×1; UA locality A-170.
6–7. Articulated valves, USNM 339814; length 50.7 mm, height 40.0 mm, thickness 17.5 mm, ×1; USGS locality M7140.
6. Dorsal view.
7. Left valve.
8–9. Articulated valves, USNM 339815; length 38.1 mm, height 28.2 mm, ×1; USGS locality M7146.
8. Right valve.
9. Left valve.

10–15. ***Margarites (Pupillaria)*** new species? 109
10–12. USNM 339816; height 9.1 mm, diameter 11.2 mm, ×2; USGS locality M7146.
10. Apertural view.
11. Right-oblique view to show spiral sculpture on whorls.
12. Basal view, showing broadly open umbilicus and spiral sculpture.
13–15. UA 2490; height 8.0 mm, diameter 10.1 mm, ×2. UA locality A-170.
13. Apertural view.
14. Apical view.
15. Basal view.

16–17. ***Calyptraea*** species indeterminate 110
Internal mold, mostly decorticated, UA 2491; height 8.3 mm, greatest diameter 22.6 mm, ×1; UA locality A-170.
16. Apical view.
17. Side view.

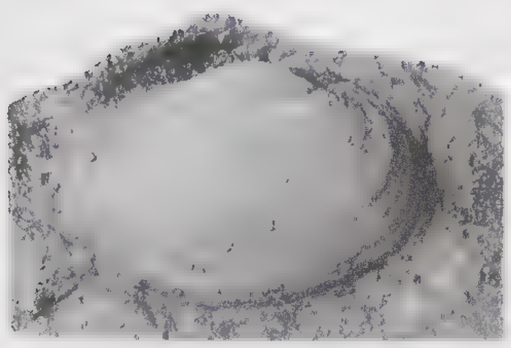
18, 23. ***Polinices (Euspira) pallidus*** (Broderip and Sowerby) 111
18. Apertural view, UA 2492; height 35.0 mm, diameter 32.9 mm, ×1; UA locality A-169.
23. Apertural view, USNM 339818; height 55.8 mm, diameter 46.5 mm, ×1; USGS locality M7139.

19. ***Polinices (Euspira) diabloensis*** (Clark) 111
Apertural view, USNM 339817; height 31.4 mm, diameter 26.6 mm, ×1; USGS locality M7140.

20. ***Bulbus fragilis*** (Leach) 112
Apertural view of juvenile, USNM 339819; showing umbilicus nearly concealed beneath thin callus; height 10.7 mm, diameter 9.6 mm, ×3; USGS locality M7143.

21. ***Natica (Cryptonatica) clausa*** Broderip and Sowerby 113
Apertural view, USNM 339820; showing umbilicus closed by thick callus; height 23.5 mm, diameter 22.0 mm, ×1.5; USGS locality M7139.

22. ***Natica (Tectonatica) janthostoma*** Deshayes 114
Apertural view, UA 2493; showing open umbilicus and sulcus above umbilical callus; height 35.0 mm, diameter 32.9 mm, ×1; UA locality A-301.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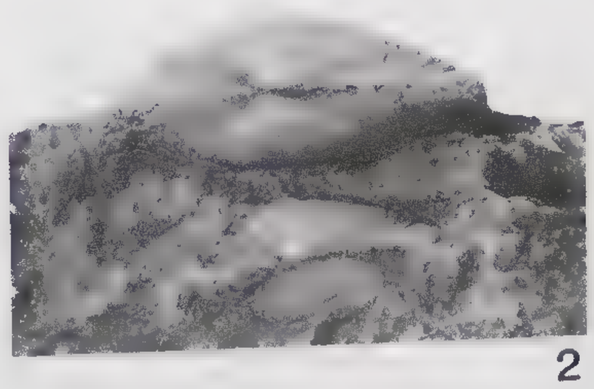
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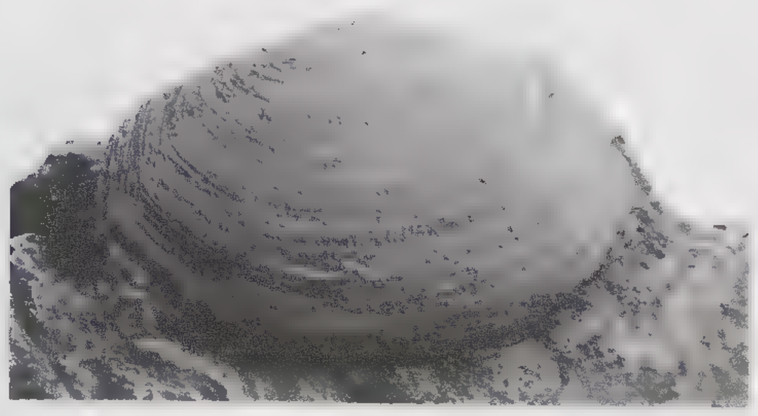
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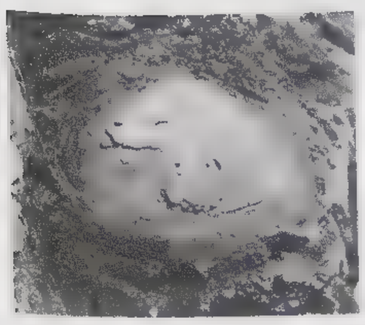
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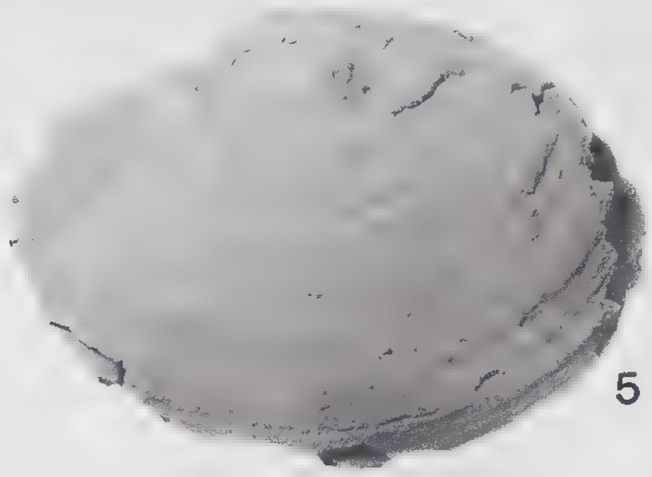
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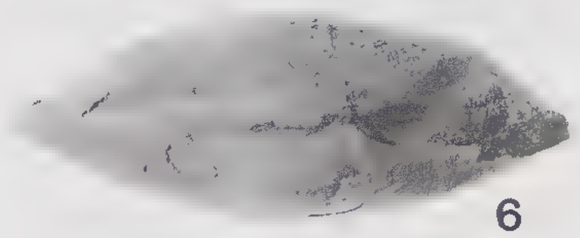
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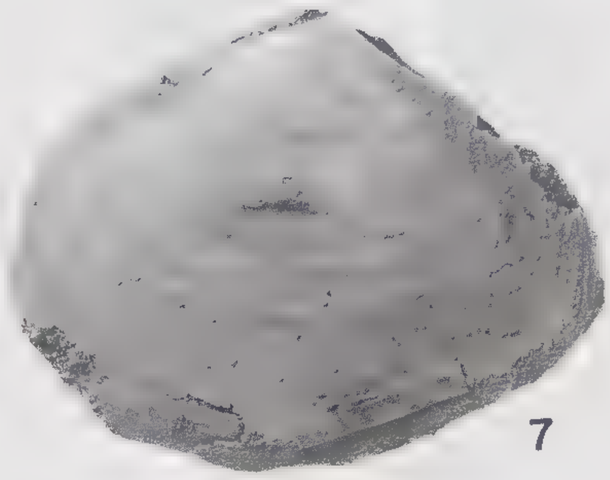
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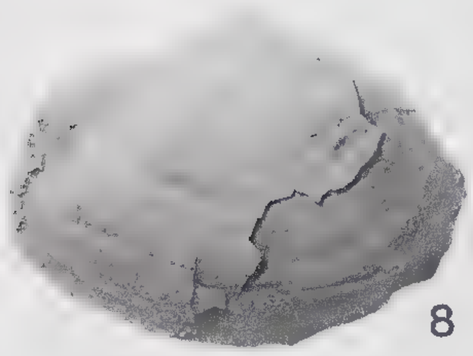
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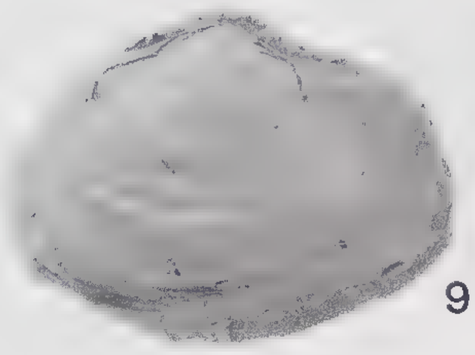
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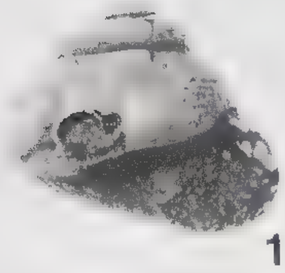
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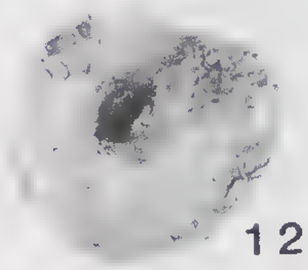
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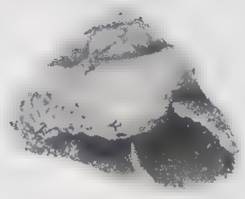
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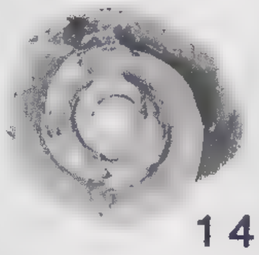
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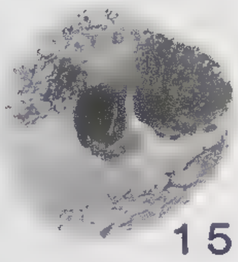
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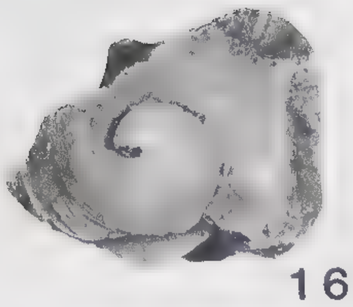
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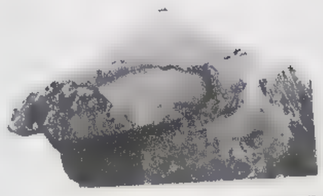
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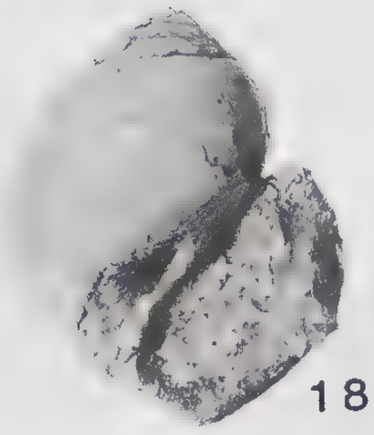
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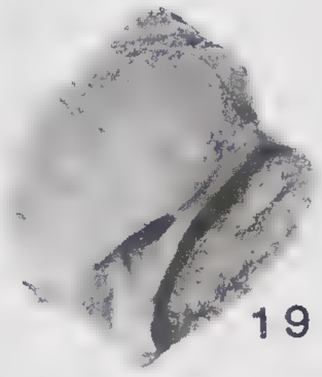
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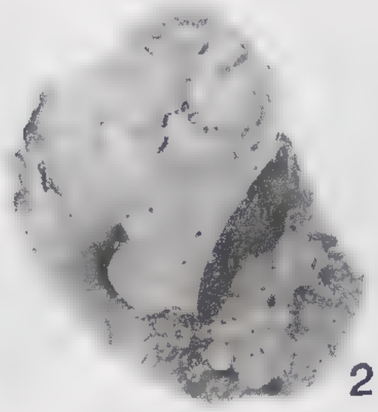
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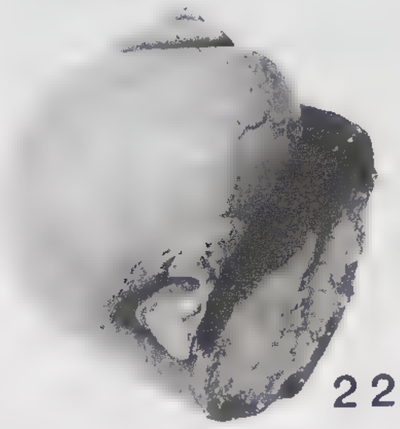
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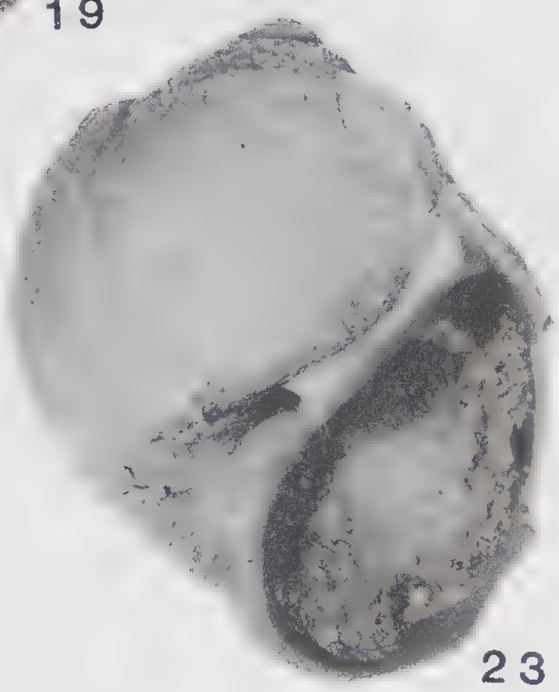
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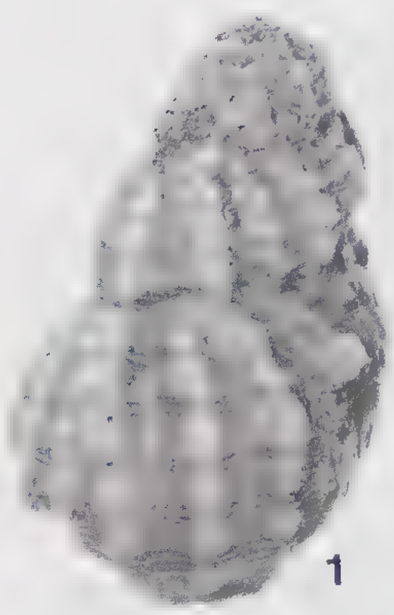
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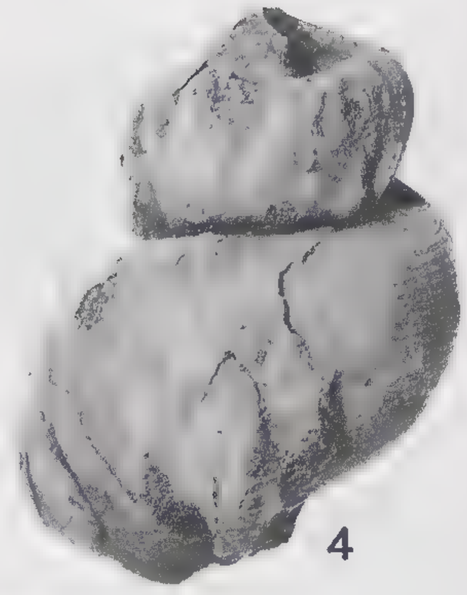
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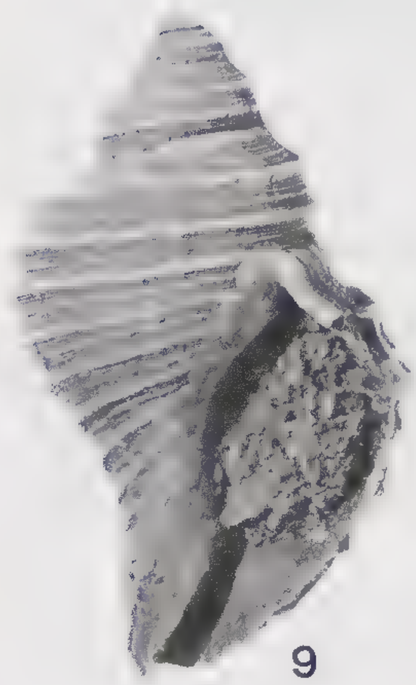
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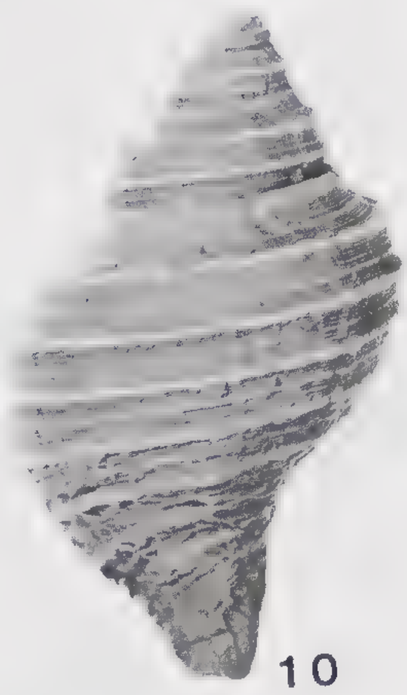
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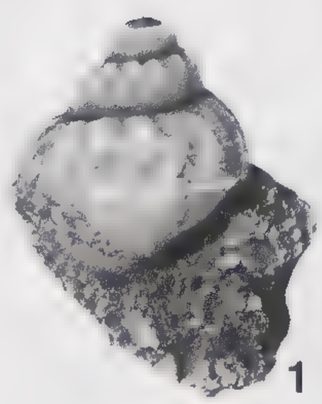
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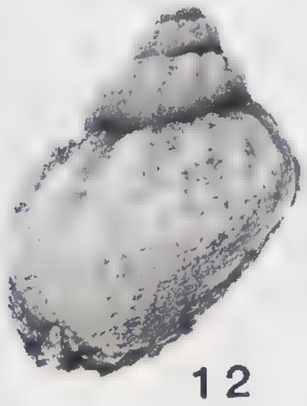
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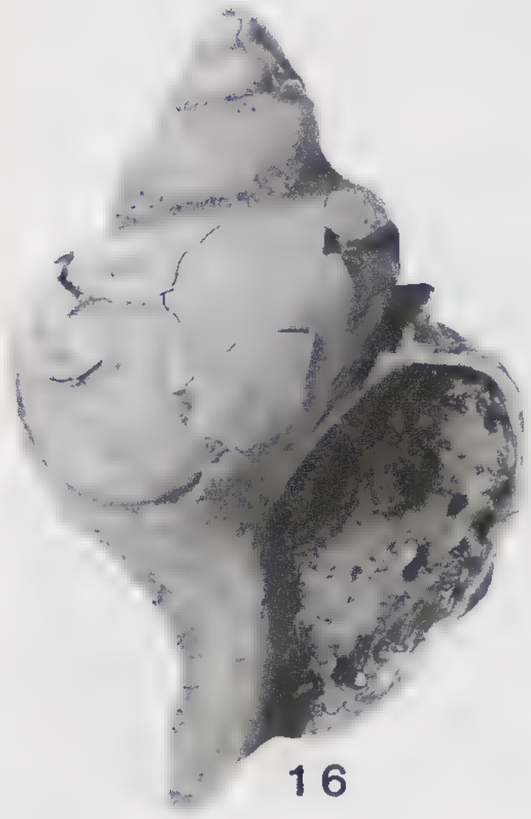
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EXPLANATION OF PLATE 23

Figure — Page

1. ***Fusitriton oregonensis*** (Redfield) 114
Backside view, USNM 339821; showing axial and spiral sculpture; height 33.0 mm, diameter 21.0 mm, ×1.5; USGS locality M7139.

2–4. ***Buccinum*** cf. ***B. planeticum*** Dall 116
2. Apertural view, UA 2494; showing spiral sculpture; height 50.0 mm, diameter 34.1 mm, ×1; UA locality A-301.
3–4. Mostly decorticated specimen, USNM 339822; showing axial and spiral sculpture; height 50.3 mm, diameter 36.9 mm, ×1; USGS locality M7146.

5–7. ***Molopophorus*** cf. ***M. bogachielii*** (Reagan) 116
5. Apertural view, UA 2495; height 30.8 mm, diameter 18.2 mm, ×1; UA locality A-301.
6–7. UA 2496; height 35.1 mm, diameter 16.7 mm, ×1; UA locality A-170.
6. Apertural view, note columellar folds and sculpture on early whorls.
7. Backside view.

8. ***Neptunea (Neptunea) lyrata altispira*** Gabb 118
Backside view of small specimen, USNM 339823; height 30.4 mm, diameter 19.8 mm, ×1.34; USGS locality M7139.

9–10. ***Neptunea (Neptunea)*** species D aff. ***N. (N.) modesta*** (Kuroda *in* Homma) of Nelson 119
USNM 339824; note fine spiral sculpture; height 56.1 mm, diameter 33.1 mm, ×1; USGS locality M7146.
9. Apertural view.
10. Backside view.

11–12. ***Cancellaria***? species 120
UA 2497; height 20.3 mm, diameter 17.6 mm, ×1.5; UA locality A-301.
11. Apertural view.
12. Backside view.

13. ***Beringius hertleini*** MacNeil 117
Partly decorticated specimen, UA 2498; height 109.4 mm, diameter 68.6 mm, ×1; UA locality A-169.

14–15. ***Oenopota*** species A 121
Mostly decorticated specimen, USNM 339827; height 9.6 mm, diameter 4.7 mm, ×3; USGS locality M7139.
14. Apertural view, showing remnants of axial and spiral sculpture.
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16–17. ***Neptunea (Golikovia) plafkeri*** Kanno 119
UA 2499; height 68.3 mm, diameter 42.1 mm, ×1; UA locality A-301.
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17. Backside view, showing subtabulate shoulder and barnacle encrustations at apex and on outer lip.

18–20. ***Oenopota*** cf. ***O. candida*** (Yokoyama) 120
18–19. Worn specimen, USNM 339825; showing axial sculpture; height 17.0 mm, diameter 10.6 mm, ×2; USGS locality M7143.
18. Apertural view.
19. Backside view.
20. USNM 339826; showing axial and spiral sculpture; height 19.0 mm, diameter 11.1 mm, ×2, USGS locality M7146.

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Table 1.—Molluscan species and localities in the Tachilni Formation. See Introduction to Systematic Paleontology for explanations of "x", "cf.", and "?"; see Appendix for descriptions of collecting localities. * = taxa too poorly preserved for confident identification to the species or genus.

COLLECTING LOCALITIES

Cape Tachilni Section ← UP SECTION | South Walrus Peak Section ← UP SECTION | Stratigraphic Position Uncertain

	M7140	M4044	M7139	M7202	M7203	M7141	M7201	M4045	M7200	M7142	M7143	M7144	M7145	M7146	M309	M310	M5163	M5166	M5167	M5168	M5169	M7149	M7150	M7204	M7256	M7258	A-169	A-170	A-301	A-302	CAS 60278	CAS 60279	CAS 60280
Bivalves																																
Acila (Truncacila) empirensis														cf.	cf.								cf.				x					
Acila (Truncacila) ermani	x														cf.																	
Chama sp.?																															x	x
Chlamys (Swiftopecten) cosibensis cosibensis	?	x	x			x								x	x		x										x					
Clinocardium cf. *C. ciliatum*														x														x		cf.	x	
Clinocardium hannibali														x								x	x		cf.		x	x	x			
Clinocardium meekianum n. subsp.?	x						x							x							cf.	x	x				x	x	x			
Clinocardium cf. *C. pristinum*	x													x													x	x	x		x	
Clinocardium sp. indet.*	x		x		x				x			x													x	x						
Crenomytilus coalingensis								x	x	x									x			x	x		x			x		x		
Cyclocardia cf. *C. roundiformis*			x																								x					
Cyclocardia sakamotoi n. sp.			x											x														x				
Cyclocardia sp. A																															x		
Cyclocardia sp. indet.*																						x					x						
Felaniella parilis			x							x																		x		x		x
Glycymeris grewingki			x				x			x				x	x		x										x	x				
Lyonsia mooreae n. sp.										x																		x				x
Macoma (Macoma) cf. *M. (M.) astori*	x				x					x													x					x				
Macoma incongrua										cf.				x									cf.									
Macoma (Macoma) optiva			x										x	x					x				x		x		x	x		?	x	x	x
Macoma sp. indet.*										x													x		x							
Miodontiscus prolongatus										x												x				x						
Mizuhopecten mollerensis												x																				
Musculus (Musculus) niger														x	x																	
Mya (Arenomya) elegans			x	x		x								x			x	x				x				x		x				
Mya (Mya) truncata		x								x	x			x		cf.		x			x	x			x			x	?			
Mya n. sp.?																													x			
Mya sp. indet.*																								x					x			
Pandora (Pandorella) grandis			x								x			x																		
Panomya izumo																							x				cf.					
Panomya trapezoidis														x														x				
Periploma (Periploma) cf. *P. (P.) aleutica*	x													x																		
Peronidia aff. *P. lutea alternidentata*			x							x				x		?						x	x				x	x		x		
Protothaca (Protothaca) staleyi	cf.									x																	x					
Saxidomus sp. indet.			x																								x					
Siliqua cf. *S. alta*														x		x				x			x		x							
Spisula (Mactromeris) albaria			x											cf.														x				
Spisula (Mactromeris) brevirostrata														x									x					x				
Spisula (Mactromeris) polynyma		x												x							x		x		x			x		x		
Spisula sp. indet.*			x											x			x				x	x	x		x	x						
Yoldia (Cnesterium) scissurata												x		x									x		x							
Genus indet.*			x	x	x		x		x	x								x	x	x			x	x	x							
Gastropods																																
Beringius hertleini	x													x			x						?				x	x	?		x	x	
Buccinum cf. *B. planeticum*														x									x		x	x			x			
Buccinum sp. indet.*			x																				x									
Bulbus fragilis											x																					
Calyptraea sp. indet.																												x				
Cancellaria? sp.																													x			
Fusitriton oregonensis			x																									x				
Margarites (Pupillaria) n. sp.?														x																		
Molopophorus cf. *M. bogachielii*																							?					x				
Natica (Cryptonatica) clausa			x		x		x							cf.													x	x	x		x	
Natica (Tectonatica) janthostoma																							x						x			
Naticidae genus indet.*											x			x		x							x		x			x				
Neptunea (Neptunea) lyrata altispira		x	x								x																					
Neptunea (Neptunea) sp. D aff. *N. (N.) modesta*	x		x											x									x				x	x				
Neptunea (Golikovia) plafkeri																																
Neptunea sp. indet.*			x				x				x			x												x						
Oenopota cf. *O. candida*											x			x									x		?							
Oenopota sp. A			x																													
Polinices (Euspira) diabloensis	x																															
Polinices (Euspira) pallidus			x																													
Polinices (Euspira) sp. indet.*		x									cf.						x										x					
Genus indet.*					x									x							x		x		x							

PREPARATION OF MANUSCRIPTS

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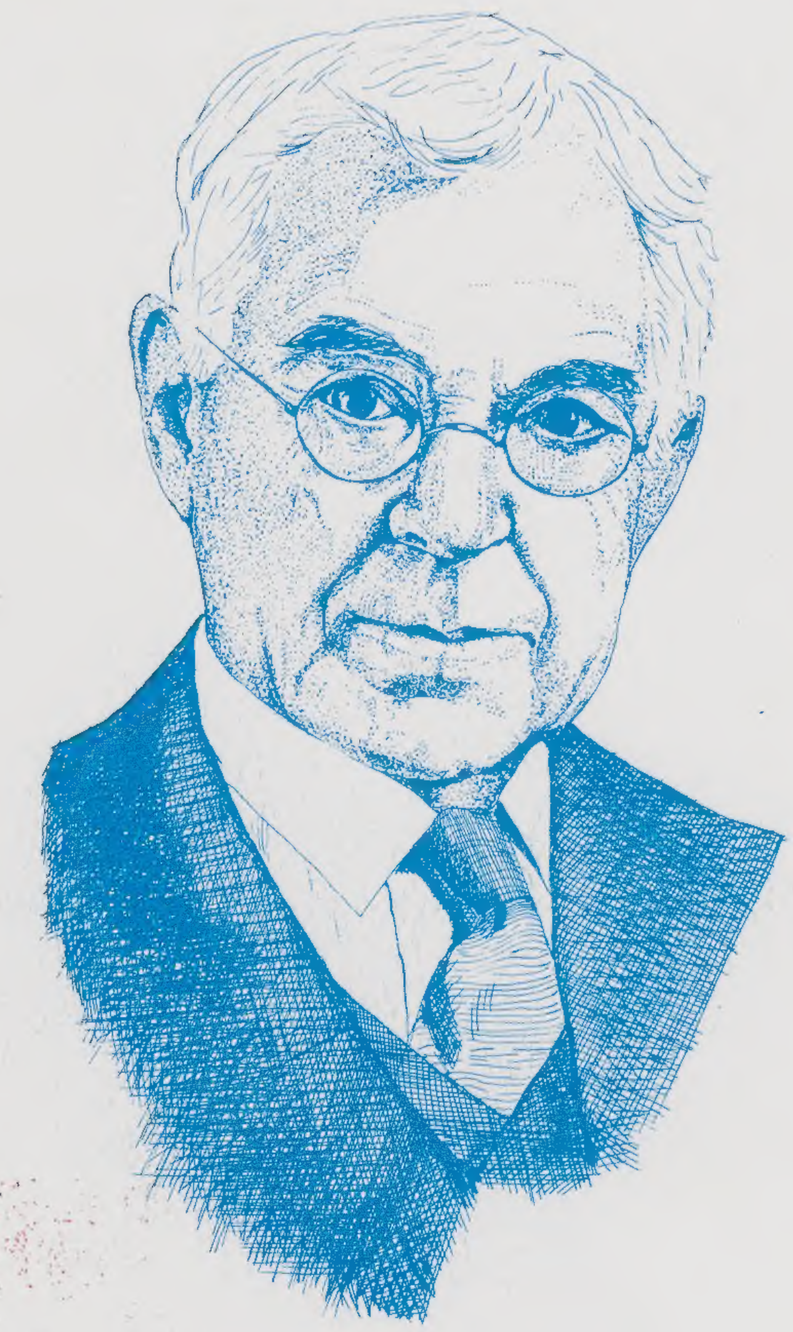

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